



ASIA EDITION

Vol. 7 Issue 3

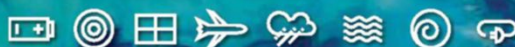
Knowledge

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INCORPORATING

SCIENCE
WORLD

CLIMATE CHANGE: PROBLEM SOLVED



Forget bags for life and energy saving light bulbs... we reveal how big ideas from science will save the planet p32

How Power Corrupts

Why dictators aren't born bad, and the character traits you might share p43

Q&A

- Why do jokes become less funny?
- Why do we hold our breath in tense situations? p85

Diet Science

Why paleo diets don't work and others do p73

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NATURE



50 10 Strangest Phenomena

SCIENCE



43 Why Power Corrupts



85 Q&A

SCIENCE



73 Pick Your Diet



32 Climate Change

Contents

Vol. 7 Issue 3

FEATURES

14 BBC Knowledge Magazine School Challenge 2014

This issue we join the boys from Hwa Chong Institution as they travel to the Heart of Borneo

SCIENCE

ON THE COVER

32 Climate Change: Problem Solved

We created many of the problems, so here's how we'll fix the planet

SCIENCE

ON THE COVER

43 Why Power Corrupts

We attempt to understand the psychology that turns leaders into dictators



NATURE

ON THE COVER

50 10 Strangest Phenomena In Nature

Nature is an artist, creating ice discs, sailing stones and weird lights in the sky that continue to baffle



HISTORY

58 Our Place In The Universe

It was more mythology than science before we figured out the Earth's position in the Universe

NATURE

64 Marine Biology

It is pretty incredible that we know more about planets in our solar system than we do about our ocean floors

NATURE

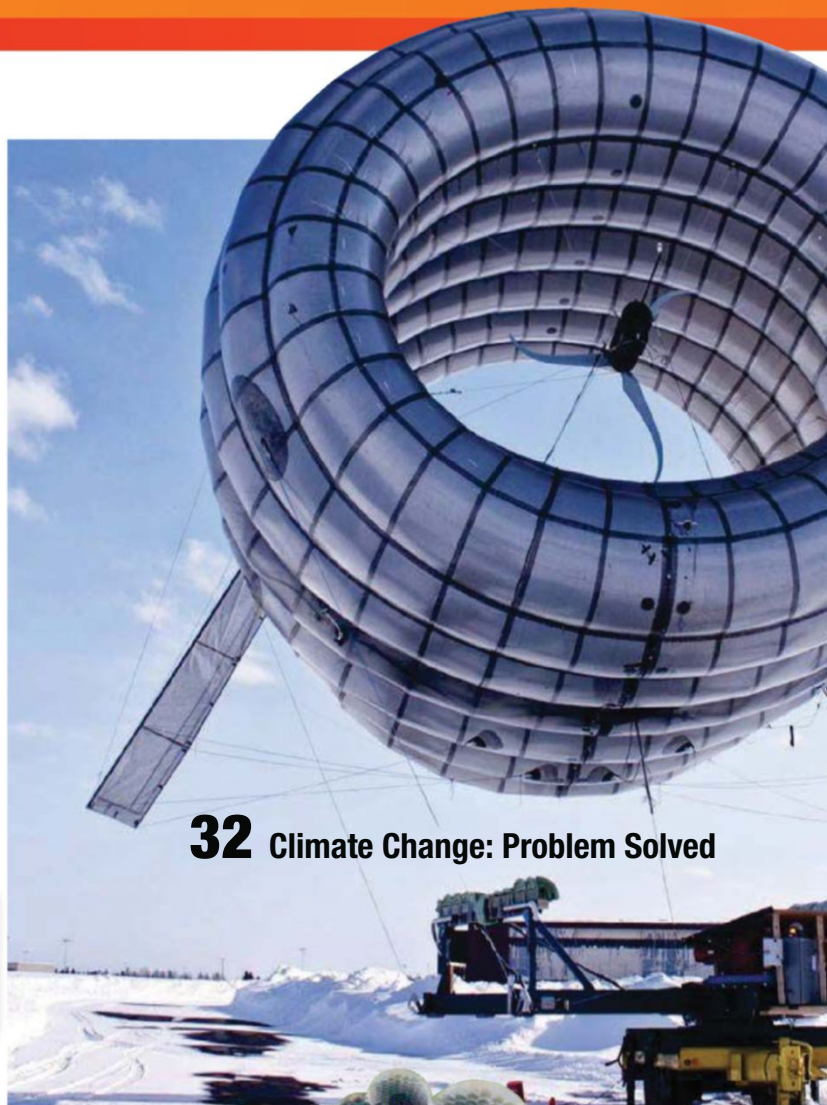
66 Vulture Restaurant

Why have the vultures of southern Asia suffered a decline, from a high of 40 million to a few thousand now?

SCIENCE

72 Hollywood Science

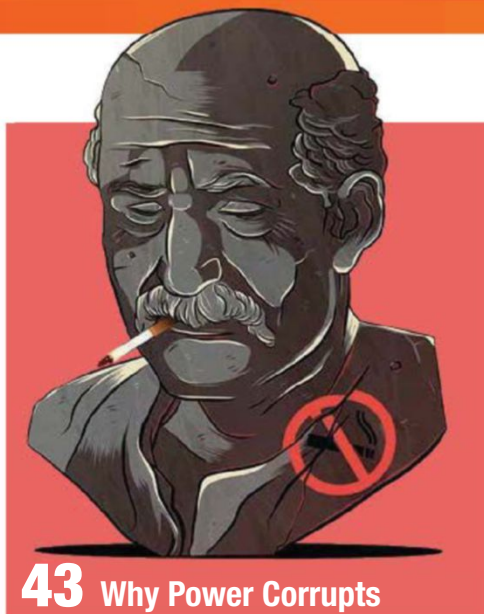
We separate science fact from movie fiction, this time we look at tornadoes in Into The Storm



32 Climate Change: Problem Solved



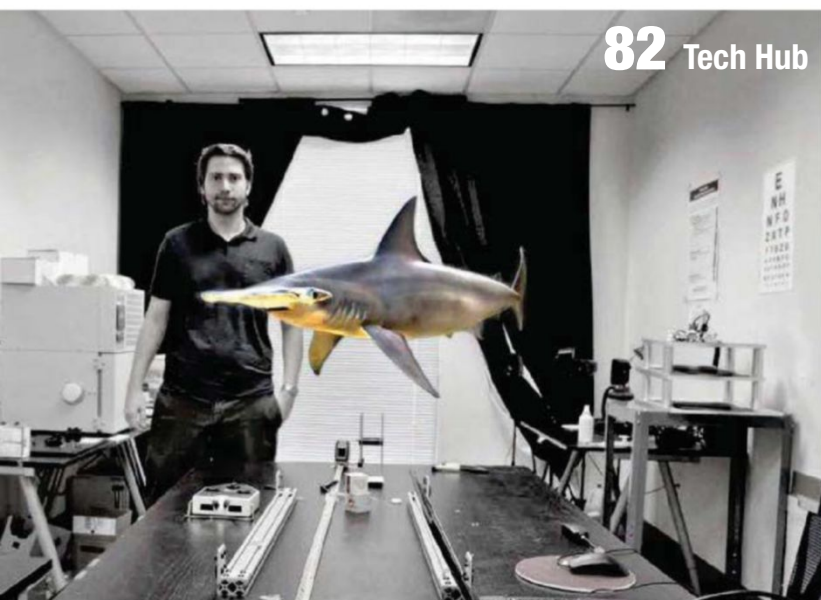
08 Snapshot



43 Why Power Corrupts



22 Update



82 Tech Hub

ON THE COVER

SCIENCE

73 Pick Your Diet

The scientific truth about the paleo, raw food, 5:2 and other trendy diets endorsed by celebrities



SCIENCE

78 Charging Up

Find out which of these four mainstream electric cars is leading the pack

REGULARS

6 Welcome

A note from the editor sharing his thoughts on the issue and other ramblings

8 Snapshot

Stunning images from the fields of science, history and nature that will astound you

UPDATE

22 The Latest Intelligence

Are we interacting with parallel universes every single day, how IT-toting insects could assist in emergency rescue, drinking cocoa prevents age-related memory loss, science's biggest projects in the year to come...

31 Comment & Analysis

The inside story of rust

ON THE COVER

85 Q&A

How do stones skim, why are prime numbers important, why do we die of old age, and more!



RESOURCE

94 Reviews

The latest science books reviewed by the experts

96 Time Out

Stretch your brain cells with our quiz and crossword

98 Last Word

We fund research – we should have access to the results



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CLIMATE CHANGE PROBLEMS WE CREATED

Through many direct as well as indirect actions of humans, we have put the health of our planet Earth seriously at risk. Rising temperatures through our endless thirst for more energy, rapid deforestation as well as increased emissions of greenhouse gases have caused temperatures to rise and the far reaching effects are being felt right now.

From the visually dramatic videos as well as images of retreating glaciers, to decreased efficiency or changes in agricultural productivity, the world is indeed in dire need for solutions to stem the destruction. The problems are so huge that one only has to refer to the recent Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change

(IPCC), a report written by hundreds of leading scientists who volunteer their time and expertise, to understand the scale of the issue.

However it is not all doom and gloom, as we have the ideas and technologies for more environmentally friendly as well as more cost effective ways of producing energy that may in-turn help to correct bizarre weather patterns. The only issue is acceptance and the speed of implementation of these ideas.

Ben Poon
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Experts in this issue...



Alistair Welch

The features editor of *Energy Engineering* magazine was the ideal person to investigate new technologies for reducing carbon emissions. Find out what Alistair discovered on p32.



Ian Robertson

Ian is a professor of psychology at Trinity College, Dublin. Ian's writing has appeared in many leading scientific journals, and on p43 he explores the minds of dictators.



Anna Kibbey

Anna is a freelance writer specialising in health and nutrition, and a regular contributor to *Men's Health*. On p73, she weighs up the pros and cons of some popular diets.



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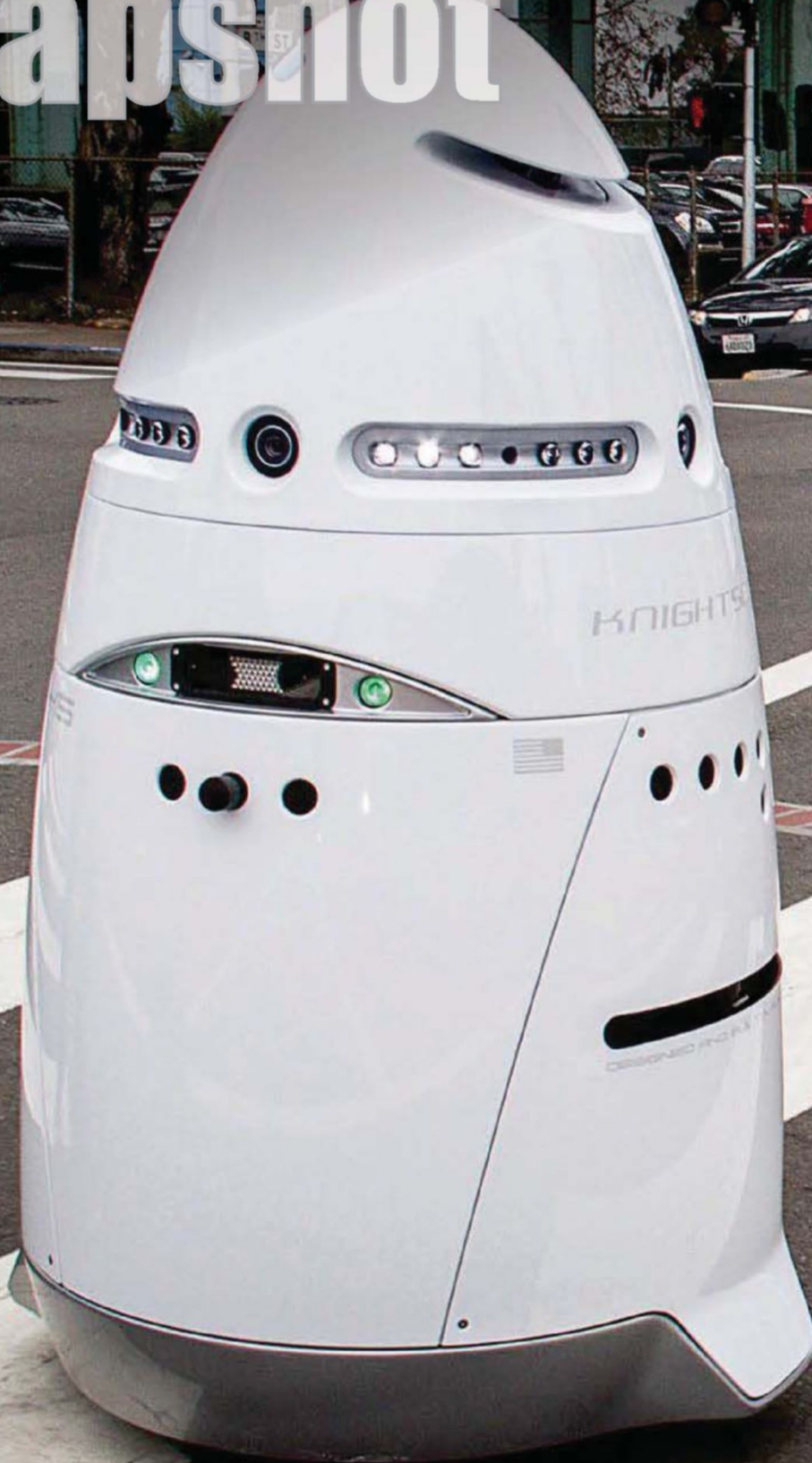


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Snapshot





Robotic arm of the law

This 1.5m-tall, 136kg robot seems a long way from the trigger-happy RoboCop of the movies. Yet according to its makers, Knightscope, the K5 Autonomous Data Machine is the future of crime prevention. The 'bot has four cameras, giving it 360-degree views day and night, plus facial recognition software, and sensors that detect heat, radiation, and nasty biological or chemical agents.

When tests begin in earnest this year, it won't replace police or private

security guards. Rather, it will help them by carrying out monotonous and dangerous tasks. "K5 can rove around outdoors 24/7, charging itself up when it needs to," says William Santana Li of Knightscope. "It can process 300 car licence plates a minute using optical character recognition."

K5 looks innocuous, but it's no pushover. "There's a piercing, very painful alarm if you mess with it," warns Li.

PHOTO: KNIGHTSCOPE

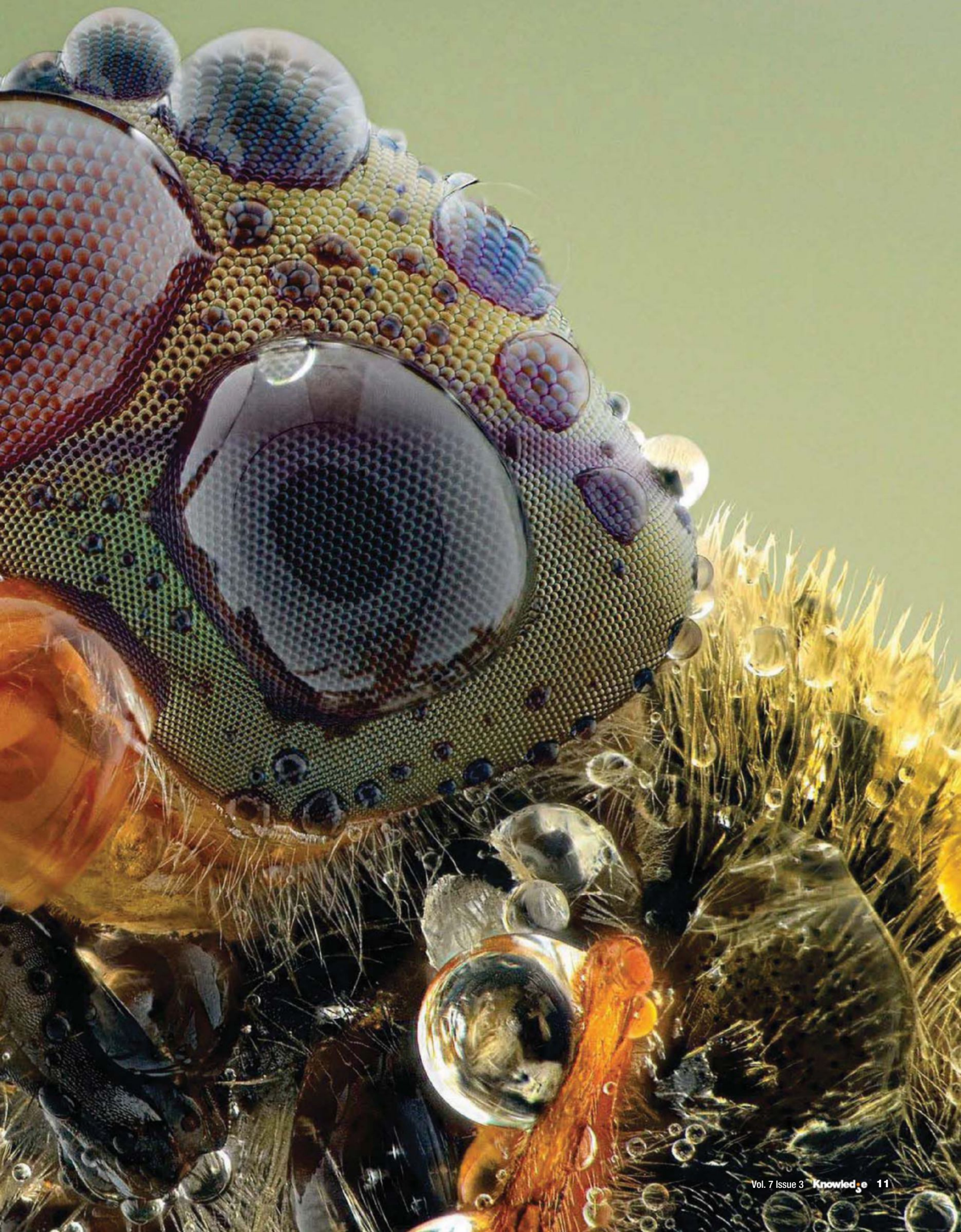
Eye drops

Although it looks like the concept art for an alien villain in a sci-fi movie, this is actually a photo of a black soldier fly. The fly only measures 15-20mm, but this image was taken through a macro lens, giving it a larger than life appearance.

On the surface of the critter's compound eye are tiny blobs of water. But why do the droplets sit there? "There is a high energy cost for a liquid to sit on a surface. A water molecule would much rather be surrounded by other water molecules, where it has a lower energy," explains Imperial College's Dr Patricia Hunt. And why are the droplets spherical? "Water has a high surface tension. It costs energy to make the surface area larger. Hence, rounded droplets with a small surface area have a lower overall energy than other shapes."

PHOTO: YUDY SAUW





The warm glow of Mach 3

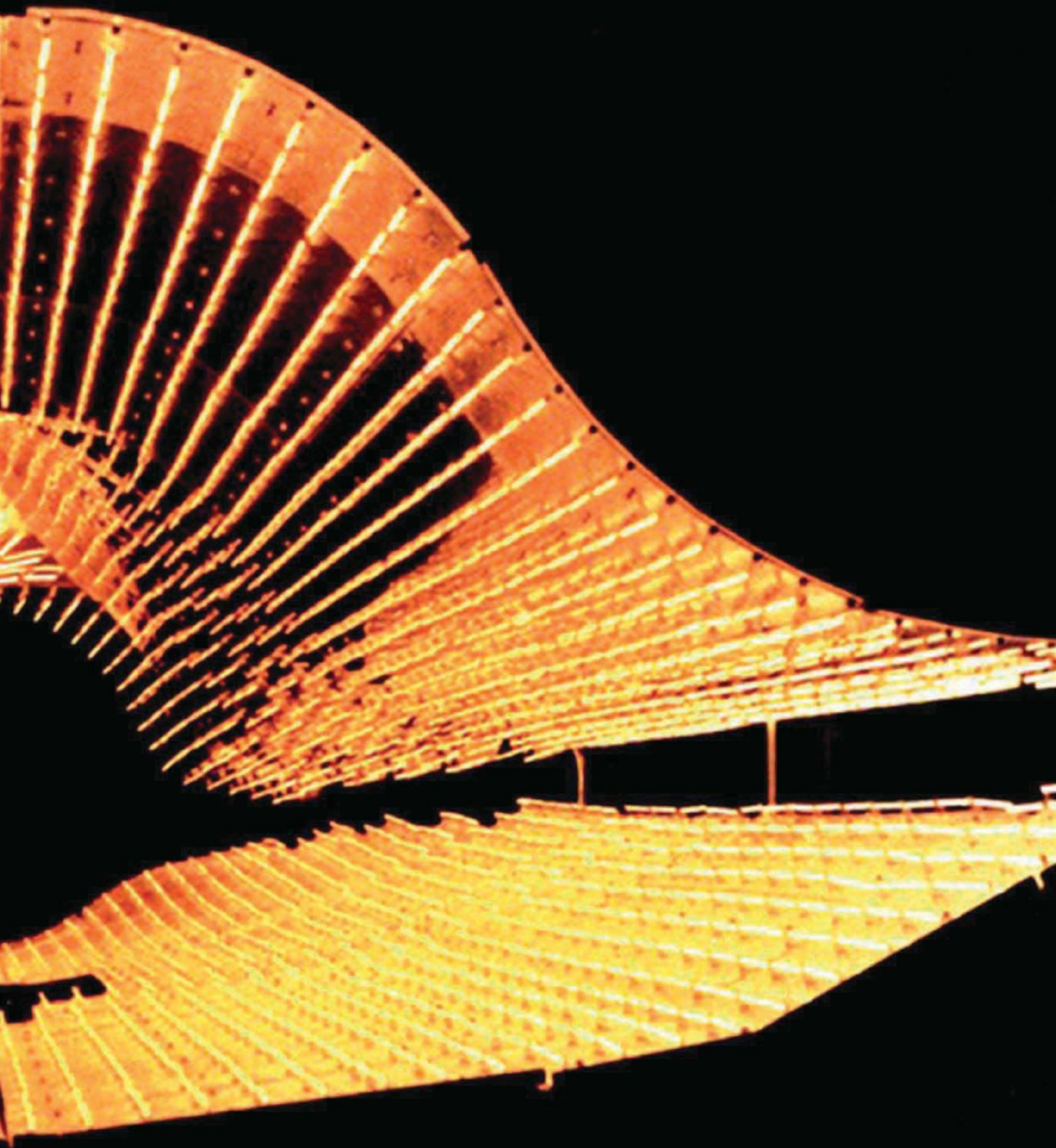
The Flight Loads Laboratory at NASA's Armstrong Flight Research Centre celebrated 50 years in 2014. It sprang into existence during the era of the X-15 rocket plane and the YF-12 and SR-71 Blackbirds, and was dedicated to testing the latest in high-speed flight.

In this image from 1971, the YF-12 fore body's radiant heating system is being tested at the Flight

Loads Laboratory under conditions experienced at Mach 3, or three times the speed of sound, over 2,000 miles an hour. Eventually the entire airframe was tested in the lab, always with the goal to collect data, validate parts and reduce risk to the aircraft and the pilots who flew them.

PHOTO: NASA





THE LAND BELOW THE WIND

Coming in a respectable second at the 2014 BBC Knowledge Magazine School Challenge, the team from Hwa Chong Institution went on a journey of discovery in Sabah

By Matin Latif

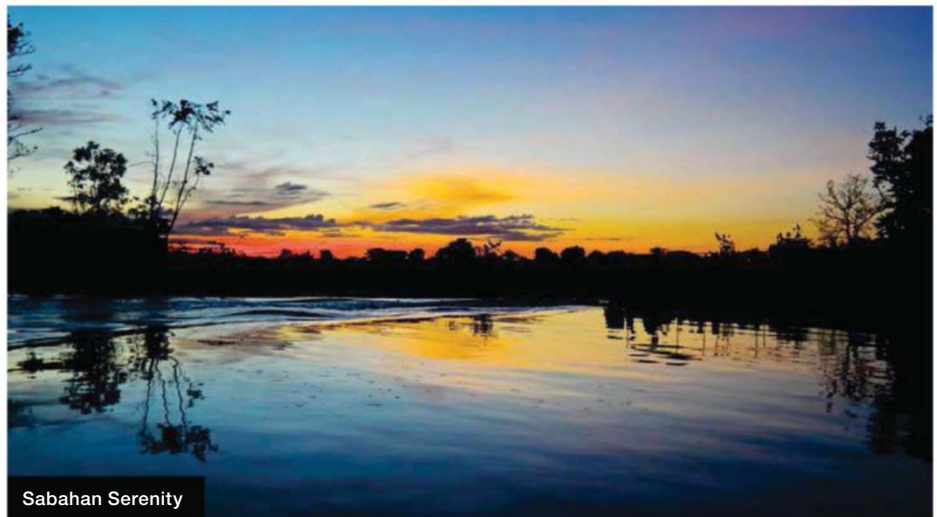


Sabah, Borneo, Land of the unmistakable Proboscis monkey and home to the head-hunters of the Kadazan, is the largest island in the world and the second largest state of Malaysia with a population of 3 million people and huge swathes of primary rainforest and countless flora and fauna making it Malaysia's prime destination for eco tourism, education and conservation of its natural wonders including the famed Mt. Kinabalu, an amalgamation of the word "Aki" and "Nabalu" in native Sabahan meaning 'Ancestor' and 'Boulder' as it is acknowledged as a sacred place to many of the diverse ethnicities living in Sabah.

After touching down at Kota Kinabalu Airport, Sean Keat Teoh, Ian Wen Yih Chia, Yao Jia Xin and Huang Zhi Zhou, the team representing Hwa Chong Institution, accompanied by their chaperone and teacher Mrs Sukhdevi Kaur were greeted by their guide for the trip Belle and Zul the driver from Amazing Borneo Tours as kindly arranged by Sabah Tourism Board. After a short ride to the town of Kota Kinabalu, the group arrived at the hotel followed by a brief overview of the coming activities before adjourning for the next day.

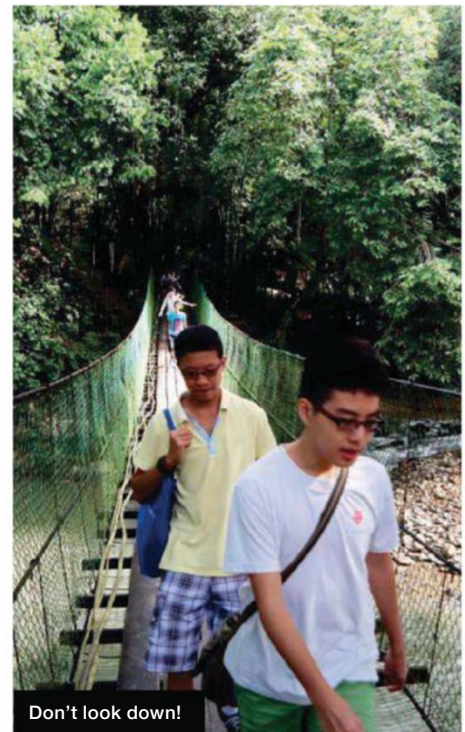
Tagal Tinopikon Park

Bright and early the next morning after a sumptuous breakfast spread, the group



departs for Tagal Tinopikon Park. The hour-long ride away from the town centre traverses the rural areas of Sabah along rolling hills to Kampong Notaruss Penampang, a village where the park is situated. Belle explains "Tagal" means "no catch" in the native Kadazan, and is a government initiative to restore the delicate ecosystem where villages are tasked to maintain the health of the river by keeping it clean and fishing is banned for a year hence the name "Tagal" and that there are around 400 such places in Borneo.

At the entrance of the village the group was met by Florence a villager, and she played host for the next few hours as she waxes lyrical about village life. A short hike down a gravel path the group crossed a suspension bridge over the river into the heart of the village where other villagers welcomed them to the sound of the village elders playing music on traditional gongs. Florence then shows a typical "modern kampong" house on stilts belonging to



her grandmother, functional in form and humbly furnished it consists of a living room, two bedrooms and an attached kitchen with bamboo flooring throughout, which provided a noticeably cooler surface to walk on. She added that it usually gets warm indoors during the day so they mostly spend their time outside and stay indoors in the night when it's much cooler.

Exiting the house the group ventured further into the village and were taught how natural latex is tapped from the bark with a specialized knife like tool that cuts grooves diagonally across the trunk of the rubber tree, allowing its white sap to flow out of the fresh cut and collect into a tin suspended at the end of the incision. Originally latex was the main source of income for the village until falling rubber prices lead the villagers to diversify their means of earning a living.



Further into the village they go!



All ready for a jungle adventure!



Taking a tour of a kampong house

As the boys and Mrs. Kaur journey even further and higher into the village grounds, Florence stops and points out a local carnivorous Pitcher plants and the well known “Tongkat Ali” plant with roots that are claimed to be good for your health and vitality not unlike the root of the Ginseng plant. Finally reaching the goal of their hike into the forest, the group stopped at the top of a lovely rock waterfall with crystal clear and ice cold water, for a photo op and a much welcomed respite from the hike.

After a couple of selfies, they were led by Florence downstream to a smaller waterfall with a small plunge pool beneath it and were instructed to remove their footwear and sit on the rocks to enjoy a nice soak in the calming ambience of the forest with



A fantastic photo op!

the sound of the waterfall playing like a soundtrack to a movie. A rare treat indeed for our city boys!

Once rested and thoroughly refreshed, the group proceeded back down to the village where the boys got a chance to learn how to use the traditional blow-pipe, a weapon of choice for hunters of the region and slingshots which they found much more of a challenge. They then feasted on a home cooked Kampong lunch made with locally sourced produce of fishes, pineapples and yam stalks and were entertained with a traditional harvest dance. After lunch the group headed down to the river bank to feed the fishes and in return, received a free “fish spa” as the fishes nibbled at the dead skin cells on their feet just like the commercial fish spas expect the fishes here were much larger!

The boys and Ms. Kaur then went for a swim in a natural pool a little further upstream by the edge of a naturally formed dam where the strength of the current is safe enough for the boys to enjoy a nice cool dip in the river.

Klias Wetlands

After bidding farewell to their welcoming hosts in the village, the group began a



An unforgettable experience!

two-hour journey to the Klias Wetlands for a riverboat ride in search of the Proboscis monkeys endemic to the island. The Proboscis Monkey is one of the largest species of primates in Asia and is easily recognizable by its large nose from which its name is derived from.

Boarding the boat, it was a leisurely glide along the river and the group eventually caught sight of a handful of monkeys and observed them for a good twenty minutes swinging about the treetops where they will spend the night

munching on local fruits till the next morning. The sun eventually began to set, signalling the return to the boathouse for dinner. Then began an unveiling of a marvellous masterpiece crafted by nature, as the setting sun turned the sky into orange and blue hues bedecked by fluffy clouds as far as the eye can see fringed by the dark silhouettes of the treetops lining the edges of the riverbanks.

Once the darkness fell, the group was told to look out for naturally luminescent fireflies, which was at first were hard to spot but once the eyes gradually adjusted to the dark, hundreds of tiny blinking lights can be seen around the trees. And in the absence of light pollution from the city, the wide expanse of sky above showcased an infinite number of stars, a great end to an exciting day.

Borneo Reef World

After a bright and early breakfast, the group was once again on a boat ride across open water to the nearby Gaya Island, Northwest of Kota Kinabalu. The far side of Gaya Island at the Borneo Reef World Pontoon, is Southeast Asia’s largest pontoon for water and sea sports activities with facilities for scuba diving, under water sea walking and a submerged viewing platform for those who wish to stay dry.

The boys and Ms. Kaur gamely suited up for sea walking, after a quick technical and safety briefing, one by one



One of many boat trips for the boys



Trying their hand at rubber tapping

the large and heavy plexiglass bubble dome with attached air tube is lowered over their heads coming to rest on their shoulders, while divers guide them down a submerged walkway and onto a viewing platform overlooking a small coral reef as a myriad of fishes swim all around darting through the reef and feeding on food put out by the divers.

After the sea-walking activities and lunch, the group takes another short boat ride to Gaya island where they then donned safety equipment for a hike thru a forested area up to the start point of a zip line, some 100m above overlooking the water and just under a km away from the end point. After a detailed safety demonstration, one by one they zipped across and over the water for a brief but thrilling ride.

“In the absence of light pollution from the city, the wide expanse of sky above showcased an infinite number of stars”



A skill lost to urbanisation

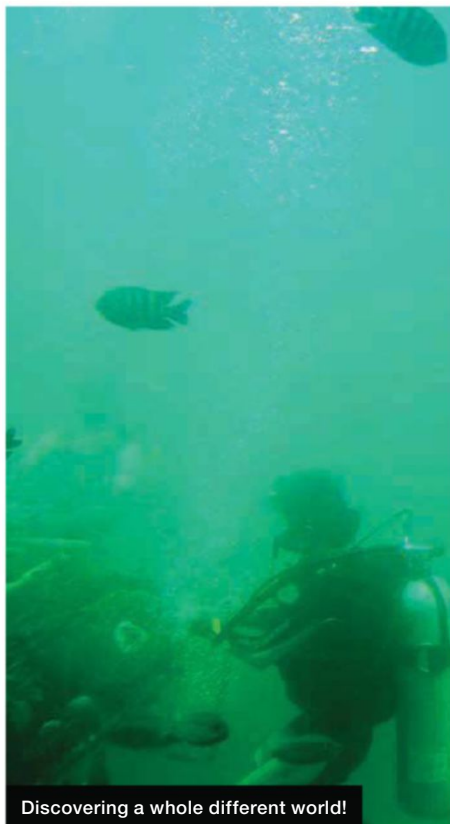


Not as easy as it looks!

Mari Mari Cultural Village

Next up was a visit to the Mari-Mari cultural village about 45mins North East of the city. The group was greeted by Kevin their guide for this segment, who then explained that the village is made up of five houses representing the 5 major tribes of Sabah. First stop was a typical Dusun house “Dusun” means farms, as they were typically rice padi farmers. The Dusun house is a simple bamboo hut low to the ground with a separate hut for storing rice. Famous for producing “Tapai” a rice wine made of rice, sugar and tobacco by women and stored in clay jars. Everyone was given a taste of traditionally prepared potato, rice and meat stuffed into a bamboo stalk and sealed with “Limping” that the boys found quite tasty.

The next house was from the Rungus tribe, traditionally they were beekeepers keeping bamboo hives where the farmed honey was consumed and the beeswax used as glue for instruments and other tools. Here the guests were given a taste of locally sourced honey. Outside the house a girl in



Discovering a whole different world!

traditional Rungus costume adorned by beads ushers the group into a long house with tree bark walls and betel nut tree flooring with thatched palm leaf roof. The Rungus is the fourth largest tribe of Sabah with settlements in the north. A single long house is home to an entire tribe with rooms along its entire length and the Chiefs room is located in the centre. Interestingly there are three doors to the whole house, two at both ends of the house for the living and one at the centre for the spirits of the dead. Here a few tribesmen provided a demonstration of fire making with dry bamboo shavings as tinder under a split half of a bamboo stalk used as its source of friction to produce fire.

They then moved on to the dwellings of the Lun Dayeh tribe, passing by a tree with a large clay jar containing a human body in the foetal position placed in it, the tribe's traditional way of burial, and after decomposition, the body will be moved to a smaller jar. The house is fronted by a large mound in the shape of a crocodile,



The area is popular with tourists as well



Enjoying a "fish spa"



A carnivorous pitcher plant

which for the Lun Dayeh who practiced Animism, represented strength and was almost godlike to them. The Lun Dayeh were the head-hunters and kept the heads of their enemies as a show of strength and as a rite of marriage. They made vests using the skin of the jackfruit tree, as armour against darts from blowpipes. Outside the house a combined chicken coop and dog kennel acted as a warning alarm of approaching people. Each house contained a family with most of the family staying in the living room and girls in a special attic where they would sleep at night with the ladders removed to protect them from attack. Heads were displayed as trophies and signs of power, the men had long hair wrapped around their necks as protection as well. Men carried machetes with tassels of human

hair, one from each they have killed. A special section of the roof was raised or lowered to allow for ventilation.

Next up was the house of the Bajau tribe, the most affluent of the tribes in Sabah, and everyone was treated to traditional sweet treats of “Kuih Jala” made from rice flour and sugar fried in coconut oil, made from dripping the mixture from coconut bowls with holes in the bottom and looked almost like uncooked instant ramen. They were also given a taste of pandan juice made with stewed pandan leaves, ginger, lemongrass and sugar, helpful for those suffering from insomnia and the boys really liked the way it tasted. The Bajau house was very large and elaborately decorated, raised on stilts and usually built over water with boats

“A trampoline where the tribesmen returning from battles were invited to jump for a prize hanging almost 5 meters overhead”



A great way to relax!



As picturesque as it is peaceful!

moored beneath and were known for being pirate's, traders and fishermen.

The house of the Murut Tribe was the most aggressive of the five houses. As the group approached a dark fenced area in a single file they hear shouts in the dark and tribesmen approach and inspect them menacingly. Once satisfied, they were allowed in and were given the opportunity to try blow darts again, this time the boys deftly hit the targets having already learnt how to the day before. The Murut Tribe's house, which is similar to the longhouse of the Rungus tribe but with a central lowered courtyard, was actually a trampoline where the tribesmen returning from battles were invited to jump for a prize hanging almost 5 meters overhead. Kelvin the tour guide demonstrates and makes it look really easy, after which all step onto the platform and bounce in unison and sing along to a traditional song signalling the end of the tour.

Before dinner, members of the troupe entertain with a performance of a traditional Bamboo Pole dance where the dancers hop and skip deftly to music between bamboo poles.

A thrilling journey

On the last day of the trip the guests from Singapore were joined by their various guides as well as Ms. Josephine Chai and Mr. Bobby Alex, both representatives from the

Sabah Tourism Board, to a delicious lunch of locally cultivated fish prepared in various ways while at the same time, the students happily regale their hosts with stories of their exciting time in Sabah. And as they bid goodbye to their gracious hosts, the boys whole-heartedly agree that their time spent in Sabah was a memorable one and the experience will stay with them for life.

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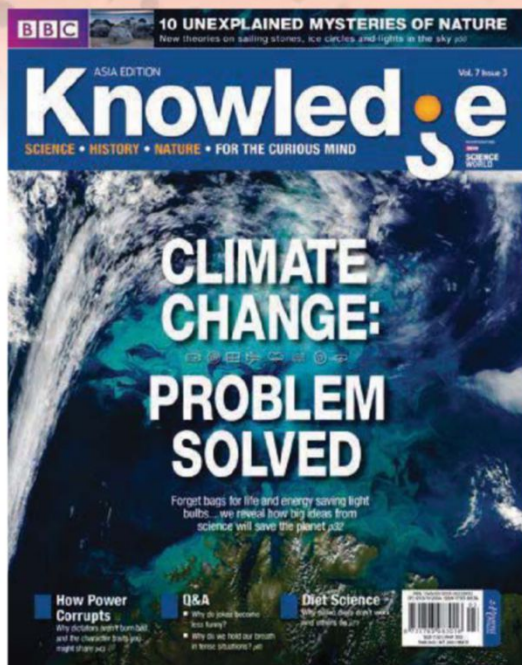
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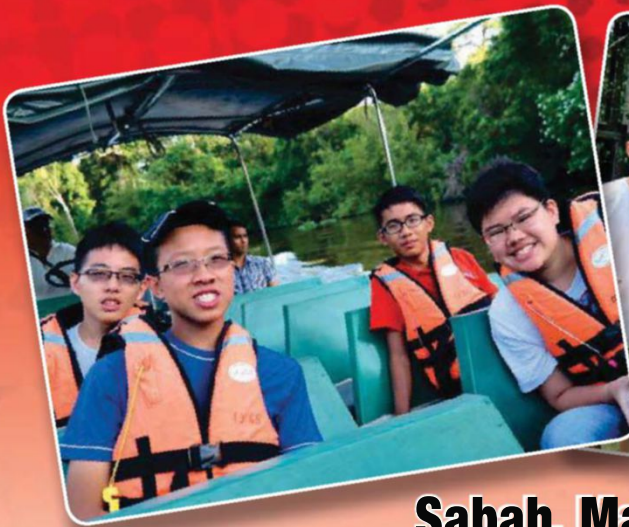


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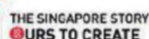
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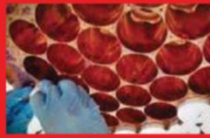
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Scientists gather data on dark matter candidates



MISSION TO PLUTO

New Horizons starts to observe Pluto



PARALLEL WORLDS MAY INFLUENCE OUR UNIVERSE

Interaction between multiple universes could help shed light on quantum phenomena

Picture a world in which the dinosaurs never became extinct. Or one that experienced nuclear Armageddon.

Well, according to research published in *Physical Review X* worlds like these may exist in universes parallel to our own. ➔

Conceptual art depicting multiple universes. Each 'bubble' represents an expanding universe



Prof Howard Wiseman proposes the existence of many interacting universes

The theory could help to explain some of the bizarre properties of quantum mechanics, such as the ability of quantum particles to occupy multiple states simultaneously until being measured, and then falling into a single state. This differs from classical Newtonian mechanics in which particles must occupy just one single state at any given time.

“The idea of parallel universes in quantum mechanics has been around since 1957,” says Prof Howard Wiseman from Griffith University, who contributed to the research. “In the well-known ‘many-worlds interpretation’, each universe branches into a bunch of new universes every time a quantum measurement is made. All possibilities are therefore realised – in some universes the dinosaur-killing asteroid missed Earth. In others, Australia was colonised by the Portuguese. But critics question the reality of these other universes, since they do not influence our universe at all. On this score, our ‘many

interacting worlds’ approach is completely different, as its name implies.”

The idea is that the universe we experience is just one of a gigantic number of universes (‘worlds’). Some are almost identical to ours; others are vastly different. Rather than evolving independently, worlds influence one another by a subtle force of repulsion that tends to make them dissimilar.

“If there is just one world, our theory reduces to Newtonian mechanics. But if there is a gigantic number, it reproduces quantum mechanics,” says study co-author Dr Michael Hall. “In between, it predicts something new that is neither Newton’s theory nor quantum theory. We believe that, in providing a new mental picture of quantum effects, it will help us plan experiments to test and exploit quantum phenomena.”

Practical applications may include designing new drugs by understanding the behaviour of molecules in chemical reactions.

GOOD MONTH/ BAD MONTH

It's been good for: Wide-Faced Footballers



Researchers at the University of Colorado, Boulder studied the facial-width-to-height ratio (FWHR) of 1,000 players from 32 countries who competed in the 2010 World Cup. They found that those with higher FWHR were more likely to score goals, but were also more likely to commit fouls. It is thought that wider faces may be related to the amount of testosterone produced during puberty.

Happy people

University College London studied over 9,000 people with an average age of 65. The research found that people who reported the greatest feelings of wellbeing were 30 per cent less likely to die within eight-and-a-half years than more morose peers.

It's been bad for: European Birds



A research team at the University of Exeter has found that bird populations in Europe have declined by a massive 421 million individuals over 30 years. Around 90 per cent of the losses were from the 36 most common species, including house sparrows, skylarks and starlings. The decline is bad news for us too: many species help distribute seeds, while others eat insect pests.

Farming

Soil in the UK has been so heavily over-farmed that the nutrients needed to grow crops have become depleted. In fact, research suggests that we only have 100 harvests left. When compared to soil taken from urban allotments, soil in arable land had significantly less nitrogen and organic carbon, scientists at the University of Sheffield found.

TIMELINE

A history of quantum mechanics

1920

Niels Bohr proposes the Copenhagen interpretation of quantum mechanics. It says that quantum particles exist in all possible states until they are measured.

1935

Erwin Schrödinger devises his famous thought experiment in which the fate of a cat confined inside a box is linked to a simple quantum process. The cat is considered to be both dead and alive until the box is opened.



1957

Hugh Everett submits the relative state formulation, later renamed the many-worlds interpretation. It states that all possible histories and futures are real.

1987

Hans Moravec publishes a paper on quantum suicide. It looks at the differences between the Copenhagen and many-worlds interpretation.

1 MINUTE EXPERT

ATCV-1



What is it?

It's a virus that is usually found in green algae that has been found living in otherwise healthy people's throats. In full, it's called *Acanthocystis turfacea* chlorella virus 1.



That's a mouthful. Does it come from algae in ponds?

Yep. Algae are water-dwelling organisms that resemble plants but in fact belong to a separate biological kingdom. It provides an example of viral jumping, a phenomenon that occurs when viruses cross over from one species to another, as was the case with the pandemic of swine flu in 2009.



Yuck. Is this virus dangerous?

Relax. It appears to be entirely harmless to humans.



Phew. That's a relief!

Hang on. While carriers of ATCV-1 exhibit no symptoms, they were found to perform noticeably worse in a series of cognitive tests than virus-free counterparts.

When injected into mice, the virus was seen to affect the expression of genes in the hippocampus. This is an area of the brain that is responsible for memory formation, learning and spatial awareness. More research still needs to be carried out to confirm the effects.

Medicine

Dengue detection

The Institute of Bioengineering and Nanotechnology (IBN) of A*STAR has developed a paper-based disposable device that will allow dengue-specific antibodies to be detected easily from saliva within 20 minutes. IBN Executive Director Professor Jackie Y. Ying shared, "Our rapid diagnostic kit can detect a key dengue antibody from saliva that is present in early-stage secondary infection. The ability to differentiate between primary and secondary dengue infections makes it a valuable early diagnosis tool that would help to ensure timely treatment and proper care of patients."

Patients with secondary infection, who have previously been infected with other serotypes of dengue virus, stand a higher risk of developing dengue hemorrhagic fever or dengue shock syndrome. This disease poses a serious health threat, and is a leading cause of illness and death in tropical and subtropical climates. There are four known serotypes of the dengue virus, but no vaccine or medicine has been developed to treat the illness. The incubation period before symptoms develop generally ranges from 4 to 10 days after infection. Therefore, early diagnosis would

enable the patient to receive prompt medical attention and avoid further complications. Currently, dengue infection is diagnosed in the laboratory by testing the patient's blood sample for the presence of dengue antigens or antibodies. IBN's device, on the other hand, is capable of detecting IgG, a dengue-specific antibody found at the onset of secondary infections, directly from saliva painlessly in one step for rapid point-of-care diagnostics. The device is currently undergoing further development for commercialization.



Weather

Unlucky strike

According to climate scientists at the University of California, the predicted temperature increase of 4°C by 2100 may lead to a 50 per cent boost in US cloud-to-ground lightning strikes. "With warming, thunderstorms become more explosive," says assistant professor David Romps. "This has to do with water vapour, which is the fuel for explosive deep convection in the atmosphere. Warming causes there to be more water vapour in the atmosphere. If you have more fuel lying around, when you get ignition, it can go big time."

WHO'S IN THE NEWS?

Elon Musk

Over-achieving founder of PayPal, Tesla Motors and SpaceX

What has he done this time?

During a talk with students from MIT, the billionaire entrepreneur declared artificial intelligence to be mankind's "biggest existential threat" and "potentially more dangerous than nukes".

What's he worried about?

Musk likened unregulated research into artificial

intelligence to "summoning a demon". "In all those stories where there's the guy with the pentagram and the holy water, it's like – yeah, he's sure he can control the demon. Doesn't work out," he said.

He usually has an answer for everything. What's his solution?

For once, Musk seems pretty

stumped. He says that there should be some sort of national or international regulation, but his only advice is that we be "super careful" with AI technology. He also recommends that everyone reads *Superintelligence* by the Swedish philosopher Nick Bostrom, which investigates the possibility of machine brains surpassing those of humans.

DAVID SHUKMAN

The science that matters



Sierra Leone is one of the Ebola 'hotspots'. Here, a health worker sprays disinfectant



What have we learnt about Ebola in the last 40 years?

The first time I heard of the Ebola virus was during a training exercise for biological warfare. It was the early 1990s and we were filming at the US Army's base at Fort Detrick in Maryland. Obscured inside vast suits, soldiers were practising handling the victim of a deadly organism – a scene all too familiar in West Africa now.

Later, over coffee, I asked them what they feared most. Anthrax? Something genetically-engineered from a secret lab in Russia? No, none of them. The answer was Ebola.

The virus was discovered in 1976, in a blood sample gathered from an ill nun in Zaire (now

the Democratic Republic of the Congo). Soon after, its danger was recognised. The first outbreak killed as many as 70 per cent of those infected. And one of the first British researchers to study Ebola, at Porton Down in Wiltshire, became contaminated and was lucky to survive.

Scientists have since learned more about this microscopic enemy. One team unravelled the mechanism by which the virus penetrates a cell, which could lead to a medicinal method for blocking it. Another has mapped the surface proteins of the virus to help identify weak spots through which to attack it.

Vaccines, which could give people immunity, are being rushed through trials with unprecedented speed. Until now, the potential market for such drugs had been too small to attract interest from the giant pharmaceutical companies. Now, years of quiet military research into Ebola are paying off as vaccines are readied for mass production.

But for the moment, the best strategy for containing the current crisis remains the basic one of keeping patients in quarantine, tracing all their contacts and burying the dead without touching them. This is based on an understanding of

how the virus is usually passed (from close contact with victims showing symptoms).

These were the principles established by the researchers investigating that first outbreak of Ebola nearly 40 years ago. In that sense, the science has not changed. But now, in a world fuelled by social media and rumour, the difficulty lies in convincing people when to take the threat seriously (in West Africa) and when there is no need to panic.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

THEY DID WHAT?!

Researchers create 'ghosts' in the lab

What did they do?

Swiss neuroscientists created the feeling of an unseen 'presence' by manipulating the minds of

volunteers. The spooky experience has previously been reported by oxygen-starved mountaineers.

How did they do that?

They blindfolded volunteers and had them make movements with their hand in front of their bodies. The movements were then copied by a robot arm behind them that was



close enough to touch them. When a small delay in the robot's motion was introduced, the participants started to feel a 'ghostly presence' in the room.

Why did they do that?

The findings may help researchers to further understand the symptoms of schizophrenia sufferers who often report sensing unseen alien entities.

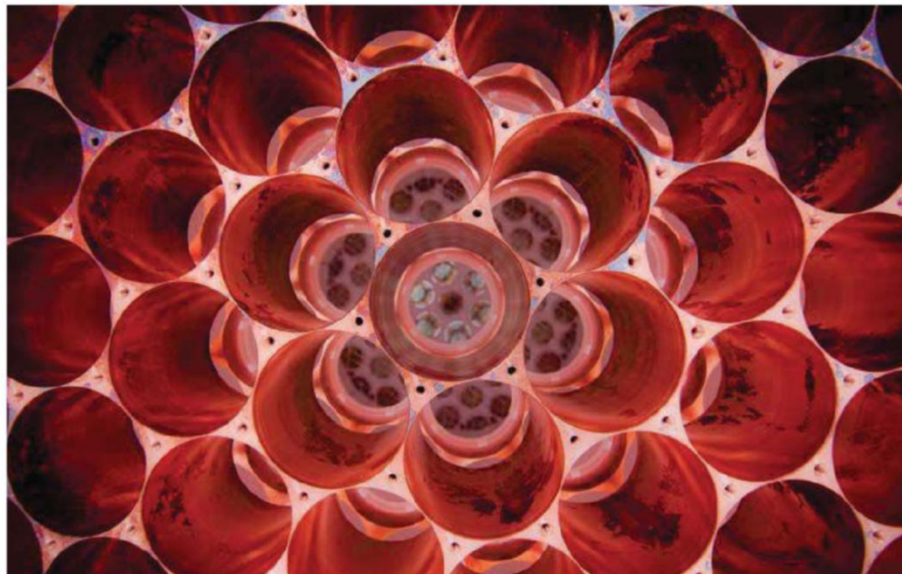
SCIENCE IN 2015

A look ahead to next year's biggest stories

Physics

LHC switches back on

Scientists at CERN will be firing up the Large Hadron Collider once more in the spring. Having found the Higgs boson, the accelerator was shut down in 2013 for maintenance. When restarted, the LHC will operate at almost twice its previous energy, allowing scientists to further investigate the Higgs and other mysteries such as dark matter.



A section of the LUX experiment's detector during construction

Hunt for dark matter

Also hoping to shed some light on dark matter next year is the Large Underground Xenon experiment (LUX). Situated one mile beneath the surface of the Black Hills of South Dakota, USA, LUX is a 370kg chamber of liquid xenon that aims to detect interactions between the

xenon nuclei and weakly interacting massive particles (WIMPs). The WIMP, a hypothetical particle, is considered to be one of the leading candidates for dark matter. The experiment is currently gathering data and is scheduled to publish results later next year.

Technology

Hydrogen-powered cars go on sale

It looks like 2015 could be the year of the hydrogen car. The next 12 months will see the launch of Toyota's Mirai, Honda's FCX Clarity and Hyundai's ix35, the first production-model cars to be powered by hydrogen fuel cells. Of course, if hydrogen fuel cells are going to enter the

mainstream then a network of filling stations will be essential. To meet this need, the UK government has pledged £11 million, to upgrade the six hydrogen fuel stations that are currently operational and build several new stations to take the nationwide total to 15.



Is Toyota's Mirai the future of motoring?

Solar-powered plane to circumnavigate the world



Solar Impulse: powered by sunshine

In another first for alternative energy-powered transport, a team from Switzerland is attempting to make the first around-the-world trip in a solar-powered plane in 2015. The group, led by psychiatrist and aviator

Bertrand Piccard and tech entrepreneur and pilot Andre Borschberg, is planning to launch its plane from Abu Dhabi in March. They hope Solar Impulse will complete the 35,000km trip around the globe by July.

Space

Mission to the asteroid belt

Dawn will arrive at Ceres in February



NASA'S Dawn spacecraft is scheduled to complete its decade-long journey to the dwarf planet Ceres and asteroid Vesta in February. The two celestial bodies lie between the orbits of Mars

and Jupiter, and it is hoped that the Dawn mission will reveal a great deal more about them, helping scientists to better understand the formation and evolution of the Solar System.

Up close and personal with Pluto

Heading out further still is NASA's New Horizons spacecraft. Since launching in 2006, New Horizons has been cruising through space on a 4.8-billion-kilometre journey to Pluto. The onboard instruments will start observing Pluto from a

distance on 15 January and continue until it makes its closest approach in July. The mission's to-do list includes investigating the geology and surface temperature of Pluto and its largest moon Charon, and examining Pluto's atmosphere.

New Horizons will vastly improve our knowledge of Pluto



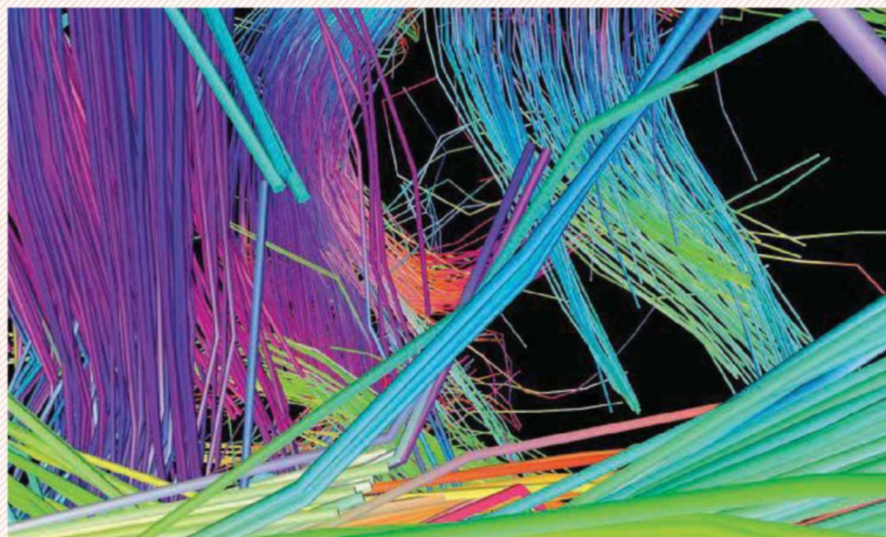
Biology

Ebola: the fightback

As the number of deaths attributed to Ebola rises daily, the need for an effective vaccine becomes ever more desperate. Trials were launched in Sierra Leone and Liberia last December, with hundreds of thousands of doses expected to be ready by mid-2015, the World Health Organization says.



A bottle of trial Ebola vaccine based on chimp adenovirus type 3



Brain connections mapped

The Human Connectome Project aims to make detailed maps of the neural connections in the human brain, to allow researchers to more fully investigate their structure and function. By the summer, Phase II of the

Nerve cell processes in the brain, taken by diffusion spectral imaging – a type of MRI scan

experiment will be complete, with MRI data having been acquired from 1,200 healthy adults. It is hoped that the project will lead to a greater understanding of disorders like autism, Alzheimer's disease and schizophrenia.



CLICK HERE

New websites, blogs and podcasts

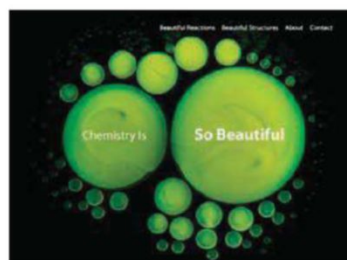


SugarScience

sugarscience.org

If news articles about sugar and its effects baffle you, look no further than SugarScience for “the unsweetened truth”. University of California scientists created the resource, which presents

a review of over 8,000 scientific papers. If you have any further questions about sugar or health, you can ask the team for help.

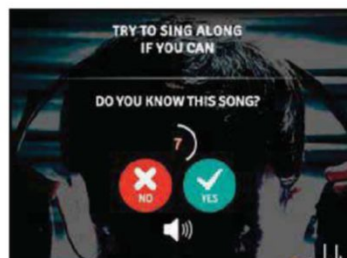


Beautiful Chemistry

beautifulchemistry.net

Science meets art in these stunning high-definition videos of chemical reactions. Beautiful Chemistry showcases a different side to chemical processes, from crystallisation to colour

change. Everyone knows that chemistry is useful, but this site shows just how beautiful it can be too.



Hooked On Music

hookedonmusic.org.uk

Have you ever wondered what makes some songs catchier than others? Hooked On Music comprises four different games that help scientists figure out just that. And it's not just for the love of

a nice melody – the research could help towards developing therapies for Alzheimer's and dementia patients in the future.



Ask For Evidence

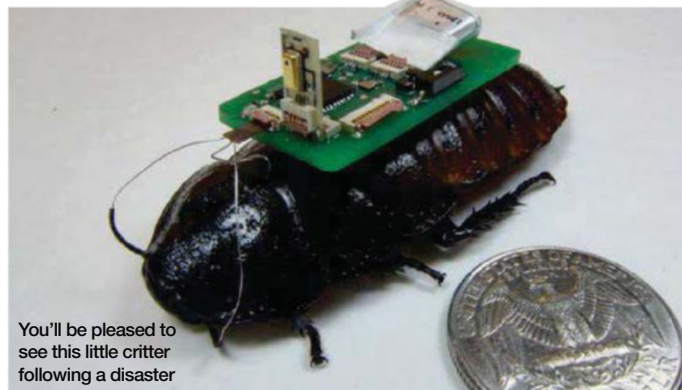
askforevidence.org

Seen any spurious health claims recently? Or something claiming to be a ‘cure’ that seems too good to be true? Ask For Evidence is a campaign (and website) run by the charity Sense About Science. It helps you ask

companies and individuals – such as politicians – for the science behind their claims, and then assesses the evidence you get.

BIOLOGY

Robo rescue roaches



You'll be pleased to see this little critter following a disaster

Under normal circumstances, seeing a cockroach scurrying across your living room floor would be a pretty unwelcome sight. However, if you were trapped inside your home following an earthquake, catching a glimpse of one of the creepy crawlies may mean help is on its way.

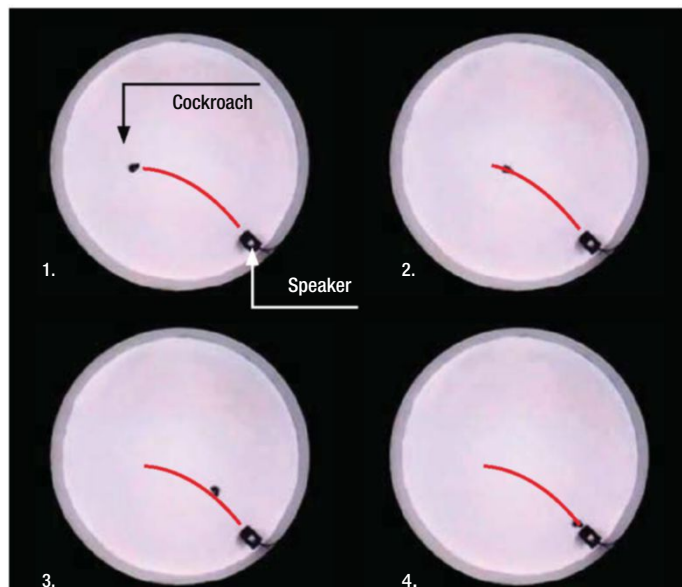
North Carolina State University researchers have developed cyborg cockroaches, or biobots, kitted out with tiny microphones that may help emergency personnel locate survivors after a disaster.

The biobots are equipped with electronic backpacks

that are linked by wires to their antennae. This allows researchers to direct the insects' movements.

“In a collapsed building, sound is the best way to find survivors,” says researcher Dr Alper Bozkurt. “The goal is to use biobots with high-resolution microphones to differentiate between sounds that matter, like people calling for help, from sounds that don't matter, like a leaking pipe.”

A second type of biobot is equipped with a microphone array that detects the direction of sound, so that rescuers can then zero in on survivors.



The robo roaches can be steered to home in on survivors' cries – in this case a loudspeaker

HEALTH

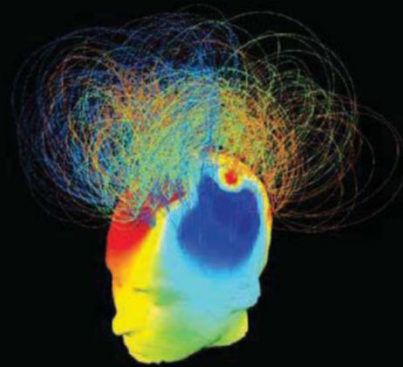
Signs of consciousness found in patients in vegetative state



The active brain network of a vegetative patient



A vegetative patient with a less active brain



Healthy individual

The team collected EEG data at the bedsides of healthy and vegetative individuals while they were resting. The EEG showed that some vegetative patients have very active brain networks

Following a brain injury, some people wake up but remain unable to communicate or make purposeful movements. They are said to be in a vegetative state.

Previously, these people were considered to be unaware of their surroundings. Now, a team at the University of Cambridge has discovered patterns of activity in the brains of people

in such states that are similar to those found in healthy brains.

Electroencephalograph (EEG) scanning and complex mathematics allowed the team to study the brain activity of 32 vegetative and minimally conscious patients. They found that some had well-preserved brain networks despite being unable to respond to any external stimuli.

When placed in an MRI scanner and asked to imagine playing tennis, these patients showed activity in the area of the brain linked to planning movement.

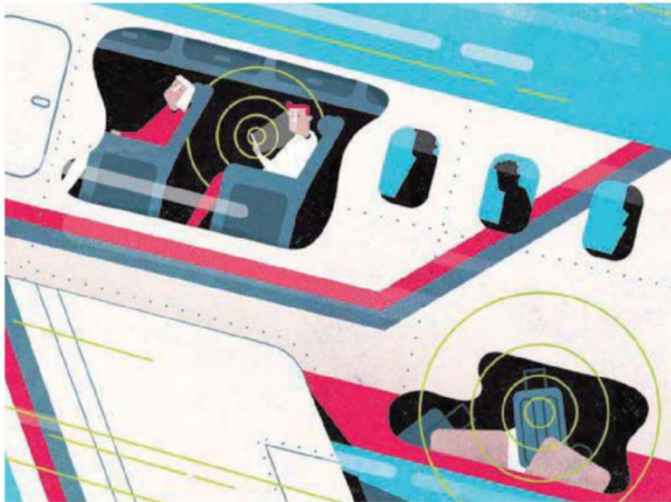
"Understanding how consciousness arises from the interactions between networks of brain regions is an elusive but fascinating scientific question," says

researcher Dr Srivas Chennu. "But for patients diagnosed as vegetative and minimally conscious, and their families, this is far more than just an academic question – it takes on a very real significance. Our research could improve clinical assessment and help identify patients who might be covertly aware despite being uncommunicative."



PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



The smart suitcase

Lost luggage may soon be a thing of the past, thanks to the Bluesmart suitcase. The bag, developed by a team in New York, is the world's first connected carry-on. It syncs with your smartphone via an app, allowing you to track its location and lock it remotely. And as you can weigh its contents via the built-in scales, you'll never have to send your case plunging into the shadowy depths of the airport's baggage handling system because it's too heavy for the cabin.

If you leave the suitcase behind – or someone else takes a liking to it – it'll automatically lock itself and let you know. Meanwhile, a built-in battery will charge your gadgets on the go, and the Bluesmart app will even access travel and weather information to provide tips on what to pack for your trip. Balaclava or bikini? Let the suitcase decide!

Patent pending

Slugs begone!

Slugs are the scourge of many a gardener, feasting on plants and vegetables like miniature killing machines. Edward Head from Devon is fed up of these marauding molluscs and has taken matters into his own hands. His slug barrier consists of rows of spikes of different lengths, creating a spiny, undulating surface that's almost impossible to slither across. The inventor hopes this approach will prove more effective than current barriers, as well as being less toxic than chemical methods.

Patent publication number: GB2513911

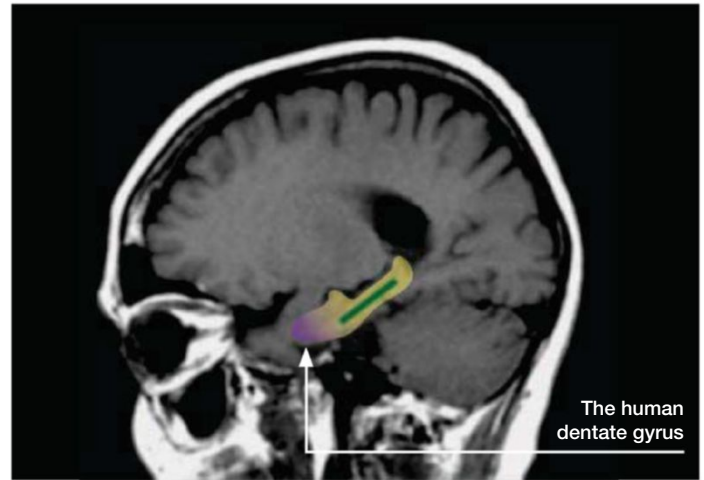
Winning whisky

Like wine, the enjoyment of drinking whisky tends to depend on the amount you're prepared to pay. For those who can't afford the top shelf stuff, Whiskey Elements, from US company Time and Oak, are wooden sticks that are dropped into supermarket whisky to transform its taste. As the whisky filters through the wood, it absorbs rich flavours and loses its hangover-causing chemicals. It's the same process that occurs with barrel-aged whisky, and the makers claim it can simulate three years of ageing in just 24 hours. Cheers!

Patent pending

HEALTH

Memory going? You should cocoa



The human dentate gyrus

Memory not what it was? The answer could be to drink more. More cocoa, that is...

It may have fallen out of favour of late thanks to fancy herbal infusions, but drinking cocoa may help to reverse age-related memory decline.

As people age, it is typical for them to experience a decline in cognitive abilities. This starts in early adulthood but is generally not noticeable until people reach their 50s or 60s. Previous work has shown that a part of the brain known as the dentate gyrus could play a key role in this process. And flavanols extracted from cocoa beans have been seen to improve neuronal connections in the dentate gyrus of mice.

To test the relationship between cocoa consumption and memory, a team at Columbia University had 37 volunteers aged 50 to 69 consume either a high dose of 900mg of cocoa

flavanols or a low dose of 10mg every day over a period of three months. Subsequent brain scans revealed marked improvements in the function of the dentate gyrus in the high-dosage group. They also performed better in a 20-minute pattern recognition test designed to evaluate the memory functions controlled by the dentate gyrus.

"If a participant had the memory of a typical 60-year-old at the beginning of the study, after three months that person on average had the memory of a typical 30- or 40-year-old," said researcher Dr Scott Small.

Sadly, gorging on chocolate will not help our memories as most methods of processing cocoa remove many of the brain-boosting flavanols found in the raw plant.

Natural compounds in cocoa beans can slow age-related memory loss



Keep your bike clean and dry to stop rust in its tracks

Today it's cold and wet, and my poor bike has cogs with an orange tinge. The places where the paint is chipped have been transformed into ugly brown patches that creep outwards from the original damage. Two days ago, the council salted the roads to prevent ice formation, therefore making the surfaces much safer. Every time I glance down at my rust-covered bike, I curse myself for not rinsing it when I got home last night. But why should I have to? Why does my bike have to pay this price in rust?

Iron is extraordinary stuff. It's very strong and cheap and endlessly useful, especially when you add a sprinkle of carbon and turn it into steel. This one element by itself makes up a whopping 32 per cent of our planet, but the odd thing is that you hardly ever find pure metallic iron in nature. You don't get little nodules of it sitting in the ground, the way you do with gold or copper. That's because it's pretty reactive, and it has almost all reacted with something else. Rust is iron oxide, which is a combination of iron and oxygen. And in the atmosphere there is no shortage of oxygen. As I cycle past bridges and cars and fancy offices with steel skeletons, it occurs to me that the real question isn't why my bike is rusting today, but why isn't it rusting every other day of the year? How have we managed to build an entire civilisation based on something so unstable?

Fortunately for us, if you just put pure iron and oxygen together at room temperature, it will be an extremely long time before anything changes. Any chemical reaction involves the shuffling and exchanging of electrons, but these two elements can't manage that by themselves.

I speed up a bit and whoosh through a puddle. Salty water splashes up on to the gears and it does more than just make them wet. It completes an electrical circuit. Iron and oxygen are unable to exchange electrons directly, but if you give the electrons a sneaky route around the back, suddenly things change. And this is what water does – it connects up the corrosion site with another bit of the metal. Even then, absolutely pure water doesn't conduct electricity very well, but throw in a bit of salt and suddenly it's a fantastic conductor. Just as importantly, this water is full of dissolved oxygen. So once I'm out of the puddle and pedalling along dry



“Electrons are shuffling through the chain and gears, and iron is being converted to iron oxide”

road again, electrons are shuffling through the chain and gears, and iron is being converted to iron oxide. If I rinse and dry my bike, I stop that process completely. If I don't, rust is inevitable. And since rust takes up far more space than the original metal, it expands outwards and flakes off.

I'm not nearly as diligent as I should be about oiling the chain, but this is the solution to the problem, for the bridges, buildings and

cars as well as for my bike. You can't stop things getting wet, but if you create some sort of barrier (oil, paint, or another metal) so that the electrical circuit can never be completed, the iron inside stays safe. It's an extremely simple solution, but it's also very effective. Even though the raw materials for the reaction are everywhere, civilisation stays up because we have eliminated the pathway to rusty trouble.

I eventually arrive at work and lock up my bike. And I promise myself that today, when I get home, I am definitely going to be good and clean and dry this long-suffering workhorse. Keeping safe the metallic iron holding our civilisation together takes constant maintenance, and I should be able to do my bit!

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series is *Super Senses*

ILLUSTRATOR: ANDREW LYONS

CLIMATE CHANGE: PROBLEM SOLVED.



It's not too late to save the planet: **Alistair Welch** and **Max Mueller** investigate the technologies that could make the biggest difference

Towards the end of 2014, the Intergovernmental Panel On Climate Change (IPCC) released its latest report, produced by over 800 scientists. It said the impact of climate change is far-reaching, both on the environment and on us. Changes linked to human activity include increases in extreme temperatures, high sea levels and heavy rain.

According to the IPCC, if climate change is left unchecked, global

warming could be irreversible by the time the 21st Century comes to a close.

But there is still hope. The IPCC says we can tackle the problem by cutting our emissions and investing in environmentally sound technologies, energy supplies and infrastructures. This, then, is *our* magazine's very own guide to the ideas and technology that could do just that. Read on to find out how we'll save our planet.



Scan this QR Code for the audio reader

“The opportunity offered by floating solar is especially appealing in countries where land is at a premium”

Set up solar farms at sea

There has been a recent drive to site solar farms in more adventurous locations to make the most of the formidable clean energy resource that is offered to us by the Sun's rays.

Such is the pull of solar power that in September 2014 the heirs to the Rockefeller fortune announced that they were to sell investments in fossil fuels. They want to reinvest in clean technology – solar photovoltaics in particular. It's an interesting departure, considering that the family made its fortune in the American oil industry.

Solar panels started on the rooftops and then moved into fields, but now developers are experimenting with constructing them on water. In September 2014, the UK's first floating solar array was built on a reservoir located on a Berkshire farm. The 200kW solar panel system will reduce the farm's energy bills as well as slash its carbon emissions.

In the UK, floating solar is attractive because deploying it avoids the criticism levelled at land-based projects that they waste valuable agricultural real estate. The opportunity offered by floating solar is especially appealing in countries where land availability is at a premium. Indeed, Japanese electronics manufacturer Kyocera recently announced plans to build the world's largest floating solar power plant. The installation is to include 11,000 PV panels over two lakes in Japan's Kato City. The sites would be capable of generating 2.9MW of electricity – enough to serve the requirements of nearly 1,000 homes. ➔




Kyocera's proposed solar power plant would contain 11,000 PV panels

PHOTO: ALTAEROS, MAKANI ENERGY

**“Now the
land and
sea have
been
conquered,
scientists and
engineers
are looking
to tackle the
skies”**





The high-flying
Buoyant Airborne
Turbine captures
more wind than
traditional turbines

Build wind farms in the sky

Wind energy is taking off. Onshore wind farms are now a common sight, while a number of new offshore sites are in the planning stages. Take, for example, the proposed Dogger Bank offshore wind farm, which is awaiting planning approval. The site will be 125km from shore at its nearest point and, when completed, will have a capacity of 7.2GW. To put this into context, its capacity would eclipse the installed capacity of all the UK's onshore wind farms put together.

Now the land and sea have been conquered, US scientists and engineers are looking to tackle the skies. Altaeros Energies, which is a spinout from the Massachusetts Institute of Technology, is currently developing a device that will generate energy from the strong, steady winds hundreds of metres above the Earth's surface.

The company hopes that its concept, the Buoyant Airborne Turbine (BAT), will be the world's first

commercial aerial wind turbine. The device incorporates a three-blade horizontal axis wind turbine – the conventional configuration we are used to seeing in onshore and offshore turbines – held within an inflatable shell. When filled with helium, it floats into the air where it is held in place by tethers at a maximum height of 600m or 2,000 feet.

At this altitude, the wind power density is three times that found at 120 metres, which is the typical height of an onshore wind turbine. The BAT features an autonomous control system that adjusts the device's direction and altitude to maximise its energy output. Electricity generated is transferred to a ground station by a connection in the tether. From here, it can be introduced to the grid or used to power equipment on site.

Initially, the company plans to develop a 30kW system with plans to scale up to 100 and

200kW devices. An array of ten 200kW BATs would thus have a similar capacity to a typical onshore wind turbine. And at a height of around 600m, it is unlikely to disrupt anyone's view of the landscape.

Altaeros is not the only player in the high altitude wind game – a range of competitors with various ingenious technologies are also attempting to get their concepts off the ground.

Makani, which was acquired by Google in May 2013, is developing an 'Energy Kite' in an effort to capitalise on the wind resource at altitudes beyond the reach of conventional turbines. The kite is a tethered aerofoil that makes huge loops through the sky. As the wind rushes across the kite it rotates four mounted turbines. Meanwhile, Netherlands-based Ampyx Power is developing an auto-piloted glider that generates electricity as the tether fastening it to the ground station is extended.



The Makani kite flies
at altitudes of up
to 305 metres

“Energy storage is a crucial aspect of a secure energy future”

Supersize batteries

The energy networks of the future will contain a higher proportion of energy from renewable sources than we have at present. But renewable energy resources are intermittent: a turbine can only generate power when the wind blows, a solar PV panel when the sun shines. This intermittency means that

energy storage is a crucial aspect of ensuring a secure energy future.

In university laboratories across the world, scientists are working on developing more efficient batteries with larger capacities and higher power densities. However, the battery is not the only energy storage solution. UK company

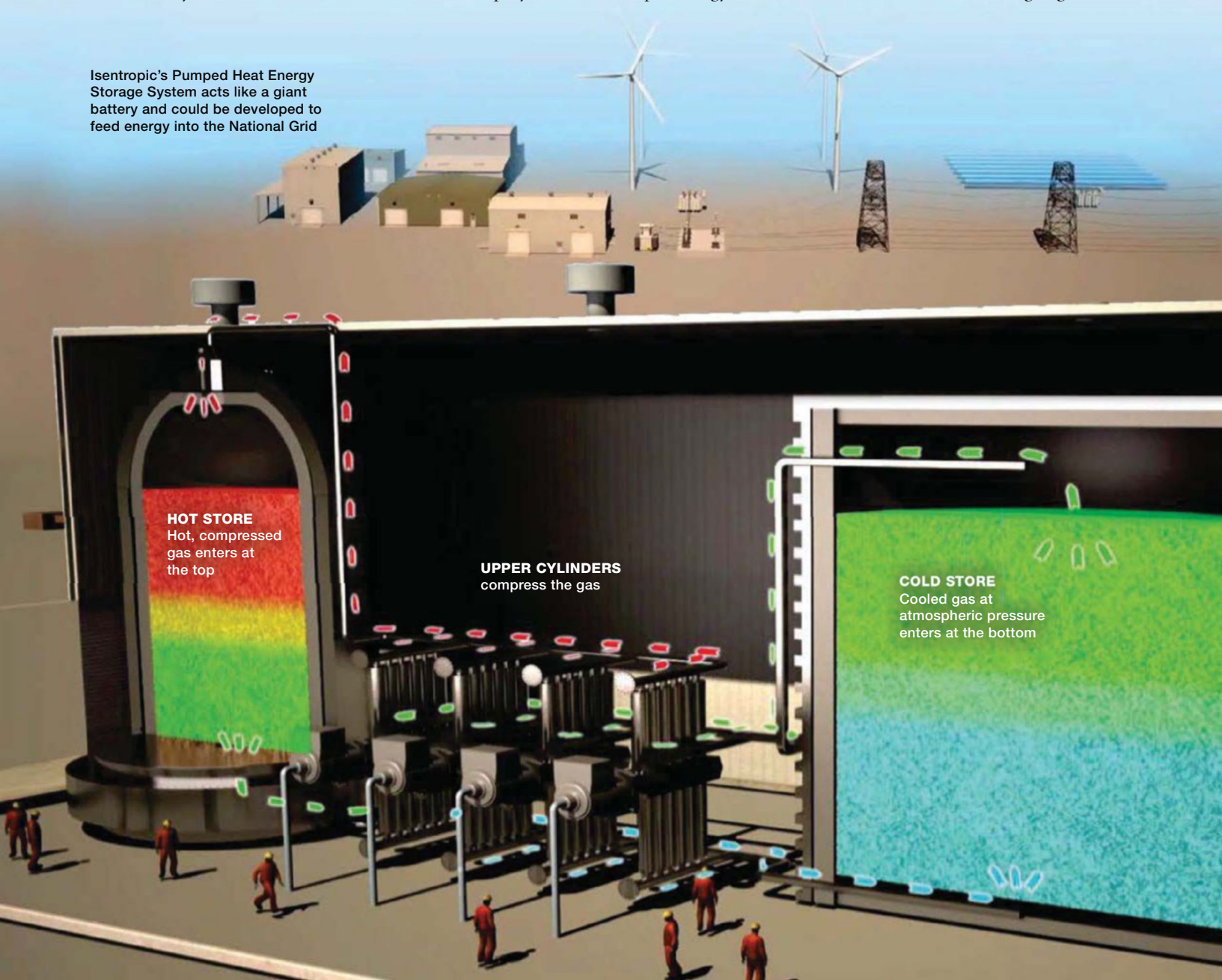
Isentropic has developed an innovative Pumped Heat Energy Storage (PHES) system.

The PHES system operates as both an engine and a heat pump. Fundamentally, electrical energy is stored as the temperature difference between hot and cold rocks. When the ‘battery’ needs to be charged, spare energy can be used to

compress argon gas until it reaches 500°C. This hot gas is then used to heat up rocks, transferring the energy and storing it temporarily. The gas emerges from the rocks at atmospheric pressure (1 bar) and a temperature of -160°C.

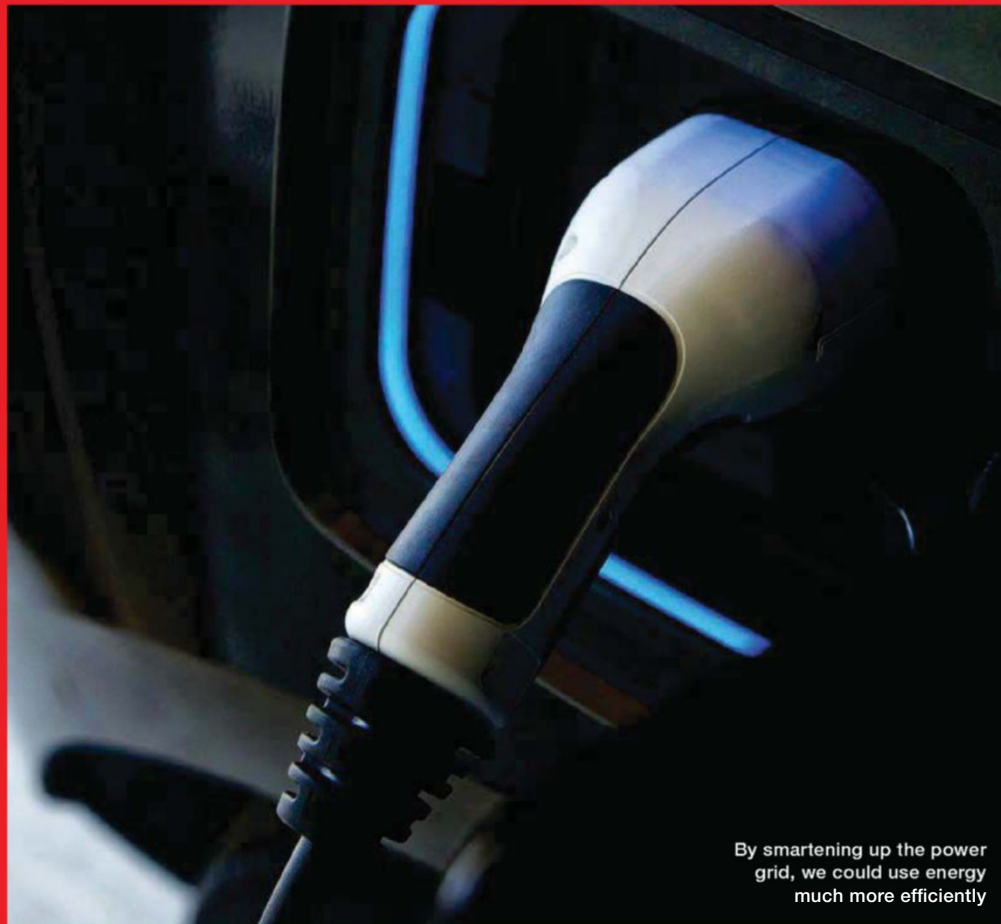
To release the energy that is stored in the rock, the process is reversed. The argon gas flows in

Isentropic's Pumped Heat Energy Storage System acts like a giant battery and could be developed to feed energy into the National Grid



the opposite direction; this causes the gas to heat up so that it can be used to generate electricity through a mechanical engine.

The company is currently rolling out small (up to 1.5MW) and medium-scale (up to 50MW) PHES systems for businesses, but has plans to develop large scale (100MW+) systems for the electricity grid.



By smartening up the power grid, we could use energy much more efficiently

Make the grid smarter

No single technology can hope to solve our energy needs. But some could make a big difference. One idea is called the 'smart grid'. The grid is the network of cables, transformers and substations that deliver electricity to your home from a power station. The smart grid is all about building intelligence into the network to make the most efficient use of energy.

It could do a lot to mitigate the impact of climate change. A US report entitled *Machine-To-Machine Technologies: Unlocking The Potential Of A \$1 Trillion Industry* was

published in 2013 by the dramatically titled US body Carbon War Room. The report estimated that smart grids could slash global greenhouse gas emissions by a fifth by 2020.

The smart grid would work by balancing the demand for energy. In future, we'll have variety of renewable energy sources, as well as innovative energy storage systems such as PHES (see left).

Take electric vehicles, for instance, which would help to reduce carbon emissions. The vehicles will need to be charged, placing a burden on the electricity network. A smart grid would help to balance this extra pressure. Imagine returning home from work and plugging in

your car. With a smart grid, the vehicle would not start charging instantly; instead, it would wait until the middle of the night when wind turbines are rotating but there is lower demand for energy.

To take this further, electric vehicles aggregated across a residential street or a company fleet could provide a useful energy storage resource. The batteries could be charged at periods of low demand, therefore making use of generation that would otherwise be surplus. At peak periods, they could return energy into the grid with the owner receiving a payment for electricity fed back in. Behind the scenes, computers will be managing demand.



PHOTO: ISENTROPIC, CORBIS

“If we’re agonising over whether we use paper or plastic, we might miss incredible possibilities”



Thinking about ‘going green’?

Dr Michael Maniates explains why saving the planet one purchase at a time won’t cut it



Can energy-saving light bulbs save the planet?

This idea that you save the world one small purchase at a time is quite entrenched. Some environmental groups have been operating off this ‘escalator’ effect. They think that if they can get us to buy an energy efficient light bulb today, it might prime us to be more politically active on energy issues tomorrow. It would be great if that theory were true. But most of the evidence suggests that small acts of consumption aren’t as politically activating as we’d hope. It makes sense that people would think that you could save the world one purchase at a time, but unfortunately it’s probably not a complete solution.

But it must help?

It does. Buying energy-saving light bulbs, using bags for life and riding your bike to work are the correct choices. They’re the *right* thing to do and it’s what we should be doing, but we can’t imagine it’s going to solve the problem. It’s important to walk little old ladies across the road but it’s not going to solve global conflict.

There is this idea that if *everyone* switched to energy saving light bulbs we could cut out something like 16 coal-powered power stations, but this idea propagates a theory of social change that says “to get anything done socially or politically, everyone has to get on board”, which simply isn’t true.

Is there any harm to it?

The danger is that you end up being drawn into a politics of guilt. So you’re doing your own little thing, but then you’ve got to convince everybody else to do the same to get anywhere. This is why we [environmentalists] never get invited to parties. Because we’re going to show up and the host is going to get criticism for using paper plates or something. I don’t think there’s a conspiracy to defang the environmental movement, but if there was, then this is what they would have us do.

What should we do?

One of the challenges is that we may have confused theology with good strategy. We want to bring everyone to the ‘church of Gaia’, but good strategy may mean just getting a few of us together to rejig these harmful systems. I think there are incredible possibilities out there and if we’re sitting at the checkout agonising over whether we use paper or plastic, we might miss them. It only takes a small number of people working together to start shifting these systems. Just get you and eight of your friends together and you can start affecting the system in interesting ways.

Farmers’ markets in the US have been a great example. The first few markets initially emerged not because of some outcry of consumer demand, but because a few people came together and made it happen. Then it became natural, and more and more opened across the US. Soon, shopping at markets rather than the superstores became the most natural thing to do for many people.

So is there hope?

In the US, about 20 per cent of the population are committed green consumers. Most people in this group see that figure and think it’s awful – they can’t believe it. But from another perspective, 20 per cent is fantastic; Gandhi would have loved those numbers. I think that’s what a lot of this comes down to: the sense of the possible and the faith in human nature to do some amazing things. If your path to a better world says that you’ve got to convince 80 per cent of people to do the same thing as you, you’re going to miss the possibility of what smaller groups can do. And of course, if you take this idea further and look at the advances in the world of science and technology, these really underscore the ability of small groups of people to make a big change.

MICHAEL MANIATES heads up the environmental studies programme at Yale-NUS College in Singapore

Make carbon valuable

Is it possible to 'clean' emissions from traditional carbon-emitting forms of energy generation so that the waste carbon dioxide never actually reaches the atmosphere? Carbon Capture and Storage (CCS) aims to do just that. Despite the various renewable energy technologies in operation or development, some carbon-emitting forms of energy generation, such as the burning of fossil fuels, will undoubtedly remain part of our energy mix.

Carbon Capture and Storage (CCS) removes CO₂ at the point of generation – at power

plants and factories, for example. The industry has been around for a little while, with the first commercial CCS demonstration taking place in 2000. Nevertheless, the tech involved is becoming increasingly sophisticated.

A CCS system involves a host of technologies linked together in a chain: the capture of carbon dioxide at source, its transportation through a pipeline, and then its sequestration (safe storage). Efforts to improve the efficiency of capture, therefore

eliminating a higher proportion of carbon dioxide from emissions, are ongoing.

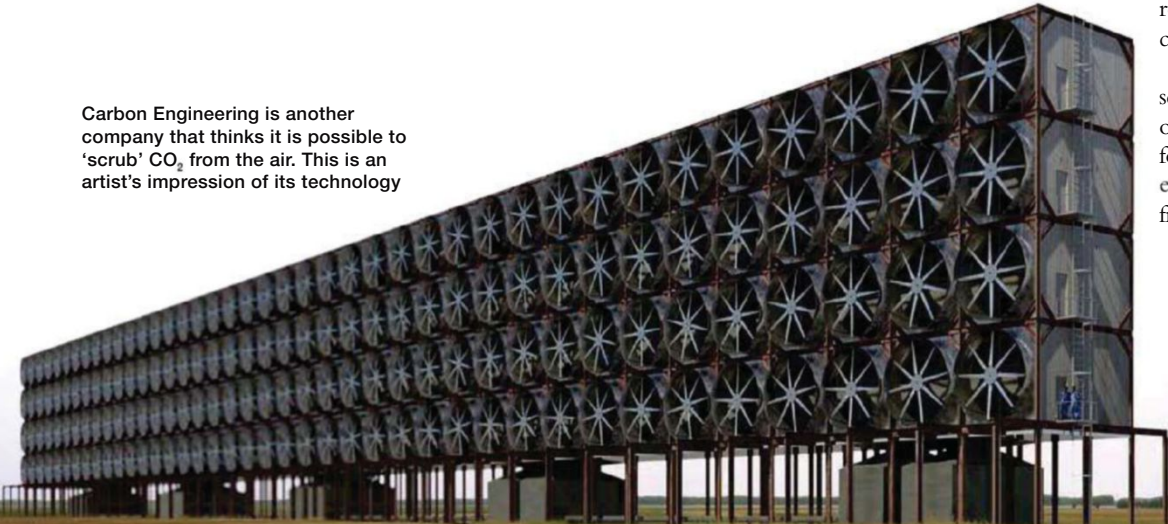
Prof Peter Eisenberger, a researcher at Columbia University in the US, is taking things a stage further and hopes to build a machine that could suck carbon dioxide out of the atmosphere. His company, Global Thermostat, has installed a demonstrator of its air capture machine in Silicon Valley. Fans within a rectangular tower draw in air over surfaces called 'contractors'. Each contractor comprises 640 cubes containing

a capture agent called amine sorbent that strips CO₂ from ambient air.

The main obstacle, as is so often the case, is money. CCS systems involve huge capital investment, so aren't necessarily that appealing to the owners of power stations. "New research and development will lead to better and lower cost solutions," says Dr Ward Goldthorpe, programme manager for CCS at The Crown Estate in the UK. "However, the real issue is the financial challenge. Currently, there is no market to dispose of carbon dioxide because society does not put a realistic price on the cost of carbon pollution."

If governments introduced schemes whereby companies were offered £50 per tonne of carbon, for example, they might be encouraged to extract CO₂ from the environment.

Carbon Engineering is another company that thinks it is possible to 'scrub' CO₂ from the air. This is an artist's impression of its technology



"There is no market to dispose of CO₂ because society does not put a price on carbon's cost"

PHOTO: YALE UNIVERSITY, ALAMY, CARBON ENGINEERING

Fertilise the ocean

Geoengineering describes ways to reduce global warming by removing carbon dioxide from the atmosphere or managing solar radiation. Taking the emphasis away from reducing greenhouse gas emissions has caused controversy, but some researchers say it's far too late to disregard the approach.

In 1988, the late oceanographer John Martin quipped, "Give me a half tanker of iron and I will give you another Ice Age". He said that a huge amount of iron dumped into the ocean would act as a fertiliser and cause plankton growth to increase. During photosynthesis, plankton draws CO_2 from the atmosphere – more plankton would mean more CO_2 absorbed, therefore slowing global warming. His idea caused enough of a storm to bring about a research effort.

"The scientific community hasn't done enough research yet to evaluate iron fertilisation as an effective carbon sequestration option," says Dr Kenneth Coale from Moss Landings Marine Laboratories, California State University. "Whether the carbon would be bound by the plankton for long periods of time remains one of the big open questions." Coale is adamant that it would need to be part of a wider strategy for CO_2 reduction and removal. "Reversing the trend would need a reduction in CO_2 emissions and a variety of mitigation measures, including geological sequestration. If effective, iron fertilisation could be part of a larger geoengineering portfolio," he concludes.

Plankton blooms, such as these in the Barents Sea, could lock up CO_2 from the atmosphere

"Give me a half tanker of iron and I will give you another ice age"

Control the rain

Drought affects ever larger areas of the planet. Most of the Arab world now falls under the classification of 'extreme water scarcity', as defined by the United Nations. North Africa and the Middle East are also facing rapid population growth – Yemen's population, for example, is expected to more than double by 2050, making large-scale water wars a real possibility.

A technology that may bring relief is cloud seeding. The use of silver iodide particles to act as tiny kernels for the formation of raindrops goes back a long way: it was pioneered in 1946 at General Electric by Bernard Vonnegut. His brother, Kurt Vonnegut, would later fictionalise the invention as Ice-Nine, a substance capable of instantly freezing all water on Earth.

Far from producing a freezing effect, silver iodide – alongside other substances such as salt or propane – is said to enhance rainfall. Cloud seeding from planes offers large savings over desalination, which costs around 50 to 60 US cents per cubic metre, according to Prof Zev Levin at the Energy, Environment and Water Research Centre of Cyprus. "If you can prove that it works, it's the cheapest solution, at three cents per cubic metre. It also avoids the need for expensive irrigation systems. The disadvantage is that it cannot be guaranteed to work when and where you want it to," the cloud and precipitation expert says.

Despite six decades of research, the jury is still out on cloud seeding. Science demands data, and comparison with unseeded clouds within the same weather system is notoriously difficult. Unperturbed, 37 countries are currently running over 150 weather modification programmes, according to the National Centre for Atmospheric Research in Colorado (NCAR). Scientists at NCAR are hopeful that their extensive statistical analysis will prove whether or not cloud seeding is feasible.

It may prevent wars. The Pacific Institute for Studies in Development, Environment and Security has recorded more than 100 conflict situations over water in the Middle East and North Africa (MENA) region. More than 250 people were killed in clashes over wells and pastoral lands in Somalia and Ethiopia between 2004 and 2006. Then again, countries might perceive cloud seeding as stealing 'their' water if they experience droughts. It may not be the panacea we're hoping for.



Cloud seeding with silver iodide from planes could produce rain to solve water shortages



Wind-powered yachts could blast seawater into the sky

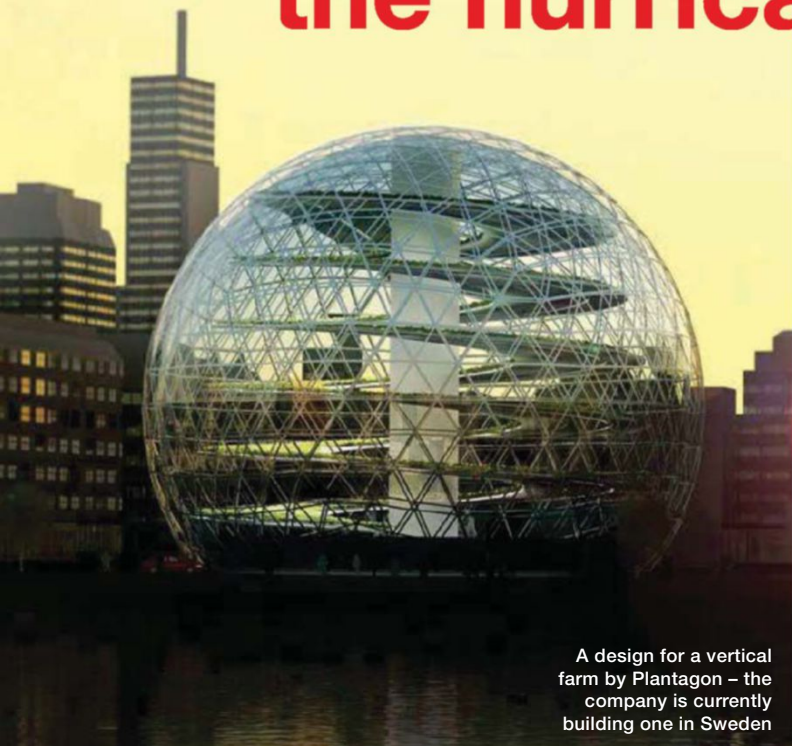
Whiten the clouds

Another discipline of geoengineering is solar radiation management. Unlike more outlandish proposals such as installing mirrors in space, scientists consider marine cloud brightening a more viable option. Researchers talk about two variants of Cloud Reflectivity Modification: cirrus stripping and marine cloud brightening. Thinning or 'stripping' high cirrus cloud would allow infrared radiation from the Earth to escape into space and result in a cooling effect. In turn, making low clouds more reflective could also reduce temperatures by taking advantage of the Twomey Effect, which is named after the Irish meteorologist Sean Twomey. The phenomenon describes how smaller water droplets lead to a 'whitening' of vapour in the atmosphere, which causes more sunlight to be reflected. Reducing

the size of the droplets can be achieved with cloud seeding techniques, such as spraying seawater solutions from ships. Researchers at the Max Planck Institute for Meteorology in Hamburg, Germany are currently evaluating the approach. Dr Hauke Schmidt has been investigating the method's outlook as part of the international Geoengineering Model Intercomparison Project (GeoMIP). "One potential side effect is that we would have to commit to the technology – probably for centuries – otherwise climate change would quickly catch up," the geoengineering specialist says. Despite this, Schmidt thinks that the benefits might just outweigh the risks, and he encourages debate: "We must recognise that these proposals are on the table. The most sensible course of action is to try and fully understand the risks, side effects and positive outcomes such interventions are likely to have."



“If you can cool the sea surface, you would calm the hurricanes”



A design for a vertical farm by Plantagon – the company is currently building one in Sweden

Farm vertically

At present, the World Health Organization estimates that half of the world's inhabitants live in cities. By the year 2050, this will increase to 80 per cent. By 2050, the world's population will have grown by three billion people and an additional space exceeding the size of Brazil will be required to grow enough food to feed everyone on the planet.

If over three-quarters of the world's food is to be consumed in urban areas, wouldn't it make sense to produce some of it in the cities themselves? It's an idea that prompted Columbia University scientist Prof Dickson Despommier to pioneer the idea of Vertical Farming. The microbiology and public health scientist thinks that in terms of area usage, his concept could outperform conventional farming by a factor of 10.

The key thought behind the technology is to grow food crops

across several storeys. There would be rotating access to sunlight or recently improved LED Grow Lights. Buildings would be put to double use, with space for office or living spaces as well as plant cultivation. “There is a duality to this. Yes, we need to produce food and conserve water. But we also need to start repairing damage to the ecosystems,” Despommier explains. “With vertical farming, every indoor acre will allow 10 acres outdoors to be returned to growing what we need to soak up carbon, and that is hardwood forests.”

Many fellow developers agree – Despommier's idea is being implemented in different guises around the world, most notably at Pasona O2 in Tokyo, Japan. This pesticide-free urban farm is open to the public and occupies the ground and first floors, while a human resource company works across the other storeys.

Hit back at hurricanes

The last two centuries have seen hurricanes claim the lives of over 1.9 million people. They cause various problems, including destruction of infrastructure and the spread of disease. Damage wreaked by 2005's Hurricane Katrina cost US\$108 billion to repair. It is likely that increasing global temperature may cause more devastating storms.

A typical Category 3 hurricane can produce energy equivalent to 10,000 nuclear bombs. Confronted with such force, can we really stop them? Billionaire philanthropist Bill Gates and British engineering professor Stephen Salter recently filed a patent with for a system of giant tubes extending 100m deep into the ocean. The system would mix water of different temperatures, therefore keeping the ocean's surface below 26.5°C – the critical level at which hurricanes form. Gates's effort is not his first. In 2009 he patented similar technology that relied on barges equipped with pumps and conduits. It was dismissed by some scientists who said the boats couldn't dredge up enough cold water within the time window offered in hurricane prediction.

This time, Gates and his team are more optimistic. Salter is confident he has fixed any problems, but thinks more funding is required. “If you can cool the sea surface, you would calm the hurricanes,” Salter says. “I estimate you would need about 150–450 of these structures. They would drift around and send out radar signals so that nothing would collide with them.”



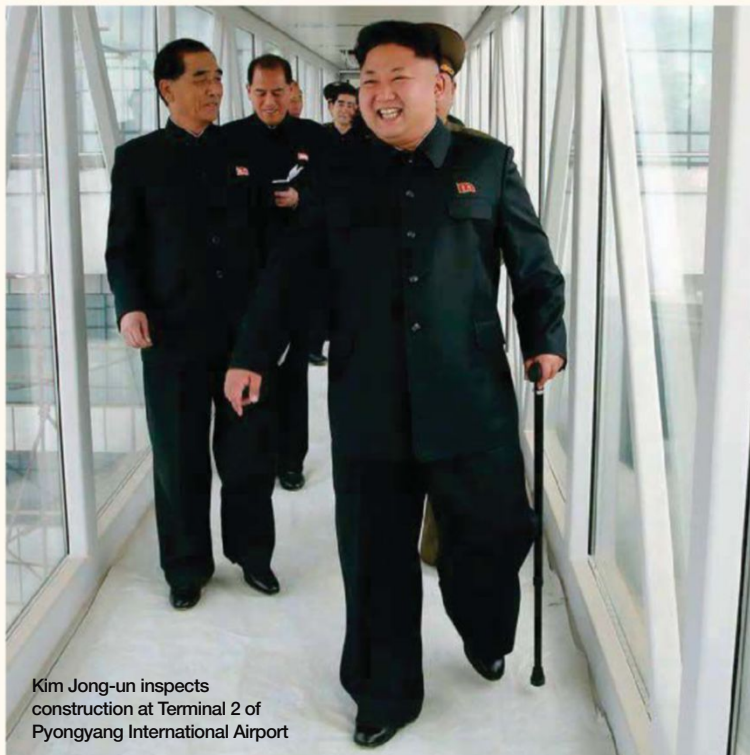
Engineering professor Stephen Salter at work in the lab on an earlier project

ALISTAIR WELCH and MAX MUELLER are science journalists with particular interests in technology and engineering

WHY POWER CORRUPTS



Three years since Kim Jong-un became the supreme leader of North Korea, **Prof Ian Robertson** reveals why ultimate power explains dictators' odd behaviour



Kim Jong-un inspects construction at Terminal 2 of Pyongyang International Airport



On his third anniversary as the world's youngest dictator, North Korean supreme leader Kim Jong-un's body is showing the strain. His recent limping reappearance, obese and diabetic, from a mysterious, month-long absence shows the physical toll his dictatorship is taking – but in what state is his mind?

Is he the “wild-eyed despot” *The Washington Post* describes him as? Or “dangerous, unpredictable, prone to violence and with delusions of grandeur”

“Hitler’s frothing, near-hysterical orations may have revealed a certain amount of deep inner turmoil”

in the words of Kurt Campbell, former US Assistant Secretary of State for East Asian and Pacific Affairs? And was he always like that, or has the experience of dictatorship forged a Frankenstein?

The odd behaviour of dictators inclines us to see them as psychologically unbalanced individuals whose very mental instability may contribute to their mad, bad drive to dominate and oppress millions of people. A top secret psychological analysis of Adolf Hitler commissioned by the US Office of

ROGUES' GALLERY DICTATORS AND THEIR REIGNS



Joseph Stalin
1924-1952
Soviet Union



Adolf Hitler
1934-1945
Germany



Muammar Gaddafi
1969-2011
Libya



Robert Mugabe
1987-present
Zimbabwe



Bashar al-Assad
2000-present
Syria



Kim Jong-un
2011-present
North Korea



North Korea is the most militarised nation in the world. This parade of armed forces marked the country's 65th anniversary in 2013

Strategic Services in 1943, for instance, alleged that Hitler had highly deviant sexual practices. These may have contributed to the fact that of the eight women with whom he had relationships in his life, three subsequently committed suicide and a further two attempted to kill themselves.

Hitler's frothing, near-hysterical orations may have revealed a certain amount of deep inner turmoil, but they also contributed to a charisma that mesmerised millions of German people. It was a spell-like effect that lived on for many years beyond his 1945 suicide.

Brutal to the bone?

While dictators can often behave oddly – the late Muammar Gaddafi's gaudy outfits and Kim Jong-un's startling haircut spring to mind – are they really the psychologically malformed monsters that the media likes to portray?

There are brutal dictators in whom there is no obvious sign of psychological disturbance. Syria's Bashar al-Assad, for instance, is a seemingly happily married family man. al-Assad has a mild demeanour in keeping with his background as a successful, London-trained physician. Robert Mugabe of Zimbabwe is a very intelligent man, highly religious, but with no obvious evidence



WHY FOLLOW A DICTATOR?

To those living in a democratic world, it can be hard to understand exactly why ordinary people would follow a dictator. But there are a number of reasons why those under a dictatorship accept the person in charge



Personality

Those with certain personality traits may be more likely to follow a dictator. People who need order and structure, who are less open to new experiences or uncomfortable with ambiguity are more likely to accept an authoritarian rule.



Anxiety reduction

In times of economic or political uncertainty, even people who would not normally be attracted to an authoritarian leader may flock to one if that leader offers relief from the threat of economic chaos, social disorder or violence. This is what happened in Germany in the early 1930s. Anxiety focuses a person's attention on the immediate threat and blinkers them to seeing a wider picture or more long-term risks.



Vicarious empowerment

Power boosts confidence, mood and optimism, while powerlessness does the opposite. The relative disempowerment of people who are at the bottom of society's hierarchy reduces levels of the feel-good chemical messenger dopamine in their brains. A powerful and charismatic dictator may offer a drug-like sense of vicarious empowerment that draws people to them.



Aphrodisiac quality

Henry Kissinger noted that power was an aphrodisiac – not only for the power-holders, but also in terms of their attractiveness to those who submit to their power. Stockholm Syndrome, where kidnapped people develop an attraction for their captors, is an example of this. In dictatorships, a proportion of the population may form a primitive bond with their leader, as happened under both Hitler and Stalin.



It's in your culture

Countries differ in how hierarchical they are. This means that there are variations in how much people lower down the social scale accept that those higher up can wield power. This is called the 'power distance index' and was devised by the Dutch social psychologist Geert Hofstede. The higher the index, the more accepting of authoritarian rule that country is likely to be. Russia is towards the top of an international league table, with a score of 93. This is beaten only by Malaysia at 104, Panama and Guatemala at 95, and the Philippines at 94. Near the bottom is New Zealand with 22, Denmark with 18 and Israel with 13.

➔ of inner trauma. Yet both these men have led brutal, atrocity-ridden regimes.

The same is true for Kim Jong-un, in spite of what *The Washington Post* and Kurt Campbell say about him. We know this because Kenji Fujimoto, the family's confidante and one-time sushi chef, was intimately involved with Kim Jong-il's inner circle and spent time with the North Korean heir as he grew up.

Kim Jong-un had a close relationship with his father – “that boy is like me” Kim Jong-il reportedly said – and he was adored by his mother. Unlike the narcissistic psychopath he is often portrayed to be, Kim Jong-un was capable of lasting friendships. This is according to flatmate João Micaelo, who was close to the North Korean over the three years they were teenage schoolmates in Switzerland.



Support group: Kim Jong-un meets gold medallists and coaches from the 17th Asian Games

FIVE COMMON CHARACTERISTICS OF A DICTATOR



Hotline to God

Success and power makes people feel special. Some start believing that God is playing a part in their greatness. Robert Mugabe announced that God helped with the constitutional changes that he introduced. Even democratically elected George W Bush claimed that God spoke to him when making decisions. Bosses can succumb to the God Complex too.



Lack of empathy

Power inclines you to treat underlings as objects. Power focuses your attention on goals and rewards and saps your ability to see things from other people's points of view because, well – your point of view is right. People with even modest amounts of power take the credit for the work of underlings, and downplay their subordinates' roles in doing the work.



Hypocrisy

Power tends to make you a stickler for getting other people to follow rules and suffer sanctions, but lax in applying these to yourself. This comes from the feeling of 'specialness' that power creates because of its positive effects on mood and optimism. This continued anticipation of success can lead to impatience with petty rules that the little people have to follow.



Micaelo describes Kim Jong-un as “a completely normal teenager”. Fujimoto recounts one occasion when, sitting in a car after an afternoon’s jet-skiing, the 18-year-old Kim Jong-un said dreamily and out of the blue: “We are here, playing basketball, riding horses, riding jet skis, having fun together. But what of the lives of the average people?” Psychopaths don’t have that sort of empathy.

Power trip

Kim Jong-un, then, is neither suffering from a long-standing narcissistic personality disorder nor is he a psychopath. This is in contrast to Joseph Stalin, for instance, whose early criminality and fractured relationships with other people justify the label.

So, if pre-existing psychological disturbance cannot explain the behaviour

of dictators, is there something about becoming one that causes them to carry out strange and appalling things? Yes there is, and the crucial ingredient is power.

Power is defined as having control over things that other people want, need or fear. Even tiny amounts of power can start to change us emotionally and cognitively. This is because power boosts the hormone testosterone in both men and women, which in turns increases activity of the key chemical messenger dopamine in the brain’s ‘feel good’ centre – the so-called reward network.

Power affects our mood through exactly the same brain mechanisms that winning a prize, being paid a compliment, having sex or taking cocaine make us feel good. Not only that, but the increase in dopamine can make us bolder, less anxious and even smarter. But there is also a dark side to power.

“[Kim Jong-un] is dangerous, unpredictable, prone to violence and with delusions of grandeur”

Kurt Campbell, former US Assistant Secretary of State for East Asian and Pacific Affairs

Are you unhappy in work? Does your manager make fun of you? Are you sick of never getting recognition? It’s very possible that your boss has dictatorial tendencies. Check off their traits with our handy guide!



Big character

Beware of a manager who likes to create emotional reactions in his underlings and subordinates. It needn’t just be fear, either. Even an apparently harmless joke at the expense of a junior colleague that causes a degree of embarrassment or confusion will do the trick as well. As can making staff grateful by some whimsical act of beneficence.



Ignore consequences

Nothing quite unties the strings of restraint as a great amount of power. A God-like sense of invulnerability arises because power inhibits our sense of risk and also eliminates any tendencies for anxious worrying about the consequences of a particular action. Even tiny amounts of power make you more likely to take the last biscuit from the tin.

Like many neurotransmitters in the brain, dopamine operates in an ‘inverted U’ shape, with either too little or too much impairing the smooth operation of the brain. Through dopamine’s cocaine-like disruption of the reward system, unfettered power can lead to serious problems of judgment, emotional functioning, self-awareness and inhibition. It also eliminates empathy and inclines you to treat others as objects, rather than as people.

In short, while Kim Jong-un may not have started out as a narcissist and psychopath, as the years go on, unfettered power may make him one.

PROF IAN ROBERTSON is the author of *The Winner Effect: How Power Affects Your Brain*. Ian tweets from @ihrobertson

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<input type="radio"/> Female	<input type="radio"/> 31 - 40	<input type="radio"/> Management	<input type="radio"/> \$50,001 - \$100,000
	<input type="radio"/> 41 - 50	<input type="radio"/> Professional	<input type="radio"/> \$100,001 - \$150,000
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10 STRANGEST PHENOMENA IN NATURE

Sliding stones, ringing rocks and pink lakes have long been unexplained by science. **Colin Stuart** examines the latest theories



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Fairy Circles

The grasslands of Namibia look like they've come down with a bad case of chickenpox. Two thousand kilometres of burnt-orange landscape are peppered with circles marked out by tufty borders of tall grass. The pockmarks seem pretty evenly spaced, and they never overlap.

Local people think that the marks are the footsteps of the gods. Meanwhile, science has been searching for a more rational answer, but no definitive explanation has been provided. Some people have pointed the finger at sand termites, which they say nibble the roots of the grass, leaving holes in which moisture accumulates. But others have ruled out that possibility. Alternative explanations have suggested that the intricate pattern is the grass's method of spreading out in such a way that it can make the most of the meagre water supply in this arid region.

PHOTO: CORBIS

Ice Discs

Reminiscent of a vinyl record spinning on a DJ's turntable, ice circles crop up in the flowing water of rivers. They have been spotted in North America and Scandinavia, as well as occasionally in the UK. They are often more than 10 metres across and are believed to form when areas of high pressure couple with a cold climate close to a river. The high pressure acts to freeze the water, but it doesn't do so all at once – little shards and cubes of ice form in the river. If those pieces then get trapped in a giant, swirling pool of water – known as an eddy – they can be sculpted into these majestic ice circles. That's the theory, anyway. Due to their rarity and spontaneous nature they can be hard to study up close. We rely instead on video footage from eyewitnesses.

PHOTO: PRESS ASSOCIATION



Lake Hillier

It is not often that you come across a pink lake. While it isn't the only one in the world, Lake Hillier's bright strawberry milkshake hue certainly makes it one of the most striking, especially when viewed from the air. Located on Middle Island, the largest of the sprawling islands of the Recherche Archipelago off the coast of Western Australia, its colour has so far defied a concrete explanation. It certainly isn't a trick of the light: fill a bottle with the lake's water, take it far away and pink it remains. "It may have certain types of algae that release red-coloured dye into its water," says Daniel Kelly, editor of the online journal *Lake Scientist*. The pinkness of similar lakes, like Salinas de Torre Vieja in south-eastern Spain, has been attributed to similar dyes, as well as the presence of red bacteria. Conclusive proof, however, remains elusive.

PHOTO: ALAMY



Sailing Stones

In the dried up lake bed of Racetrack Playa – a quiet, deserted part of the Death Valley National Park in California – a mystery has been baffling scientists since the beginning of the 20th Century. Rocks seem to move by themselves, creating long grooves in the sand as if heaved along by some invisible mischief-maker. The strange tracks can zig-zag for many metres across the arid landscape. The tiptoeing lumps of rock have been dubbed 'sailing stones'. The area was first mapped in the 1940s, with research into the phenomenon beginning in earnest in the 1970s and continuing right up until the present day. Yet a recent breakthrough may have come from teams of scientists leaving time-lapse cameras in the desert to spy on the stones. The footage points the finger at slow-moving ice melt, which shoves the stones along as it flows. Watch them in action at <http://youtu.be/uyHcs7B27Zk>

PHOTO: CORBIS

Moeraki Boulders

Rising out of the sand on Koekohe Beach on New Zealand's South Island are spectacular spherical structures. They have been named after the nearby town of Moeraki. Ranging in size from 50cm to 2 metres, local Maori tradition claims that they are eel baskets that were strewn asunder after the sinking of a legendary canoe. Scientists believe that they formed when sea sediment hardened more than 50 million years ago. The intervening time has seen them exposed as the sea has chipped

away at the land. So while their occurrence is believed to be natural, the exact mechanism that hardened the sediment is unclear. "The conditions which localised activity to produce geometrically near-perfect spheres and ellipsoids remains mysterious," says Prof Robert Raiswell, from the University of Leeds. Similar features known as the Koutu Boulders are found in Hokianga Harbour on New Zealand's North Island.

PHOTO: CORBIS

"Maori tradition claims that they are eel baskets strewn asunder after the sinking of a legendary canoe"

Klerksdorp Spheres

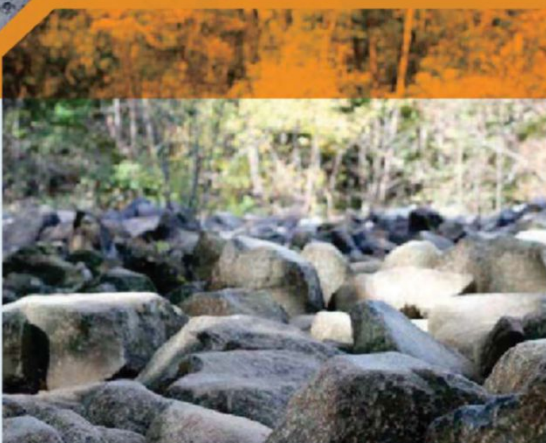
Similar to a conker, or a perhaps an indoor bowling ball, these unusual spheres have been turning up close to mines near the city of Klerksdorp in northwestern South Africa. Reddish in colour and ranging in size from 5mm to 10cm, X-ray analysis has shown them to be made of the minerals hematite and wollastonite. While some people have suggested that these spheres could only have been made by intelligent life, scientists have instead turned to the way in which volcanic deposits change as they cool. Paul Heinrich, from Louisiana State University in the US, argues that “their composition, internal structure, and frequent subspherical external shape are quite characteristic of natural metamorphosis”. They are thought to be almost three billion years old, leading some to claim them as evidence of intelligent life here on Earth before modern humans. However, Heinrich’s extensive studies of the spheres in the 1990s debunked those wild claims.

PHOTO: PAUL HEINRICH/WIKIPEDIA



Some of the Klerksdorp spheres have a groove running round their centre

Ringing Rocks



Imagine a rock that rings out like a bell when struck. Such sonorous stones can be found across the US, with the most famous examples found in Pennsylvania and New Jersey. At one site – Ringing Rocks Park – the boulders are spread over 2.8 hectares (seven acres) of forest. What makes them so percussive remains a mystery, although it could be linked to high amounts of iron and aluminium. The rocks are made

of olivine diabase, which would have originated in volcanic activity; as the area repeatedly froze and thawed over the last 12,000 years, that material broke up into the smaller pieces we see today. Some have compared the sound to the noise made when you flick the handle of a mug, although different sized rocks appear to make different sounds.

PHOTO: JEFFREY INSCHO/FLICKR

Underwater 'Crop Circles'

While the crop circles that sometimes adorn the world's wheat fields have been attributed to UFO hoaxers, an underwater variety has a more natural, if unusual, explanation: amorous fish. As far back as 1995, divers off the coast of Japan encountered beautiful circular patterns inscribed in the sandy ocean floor. The artist responsible for this subaqua graffiti turned out to be a previously undiscovered species of pufferfish. The males use their fins to create tiny currents in the water, which shift

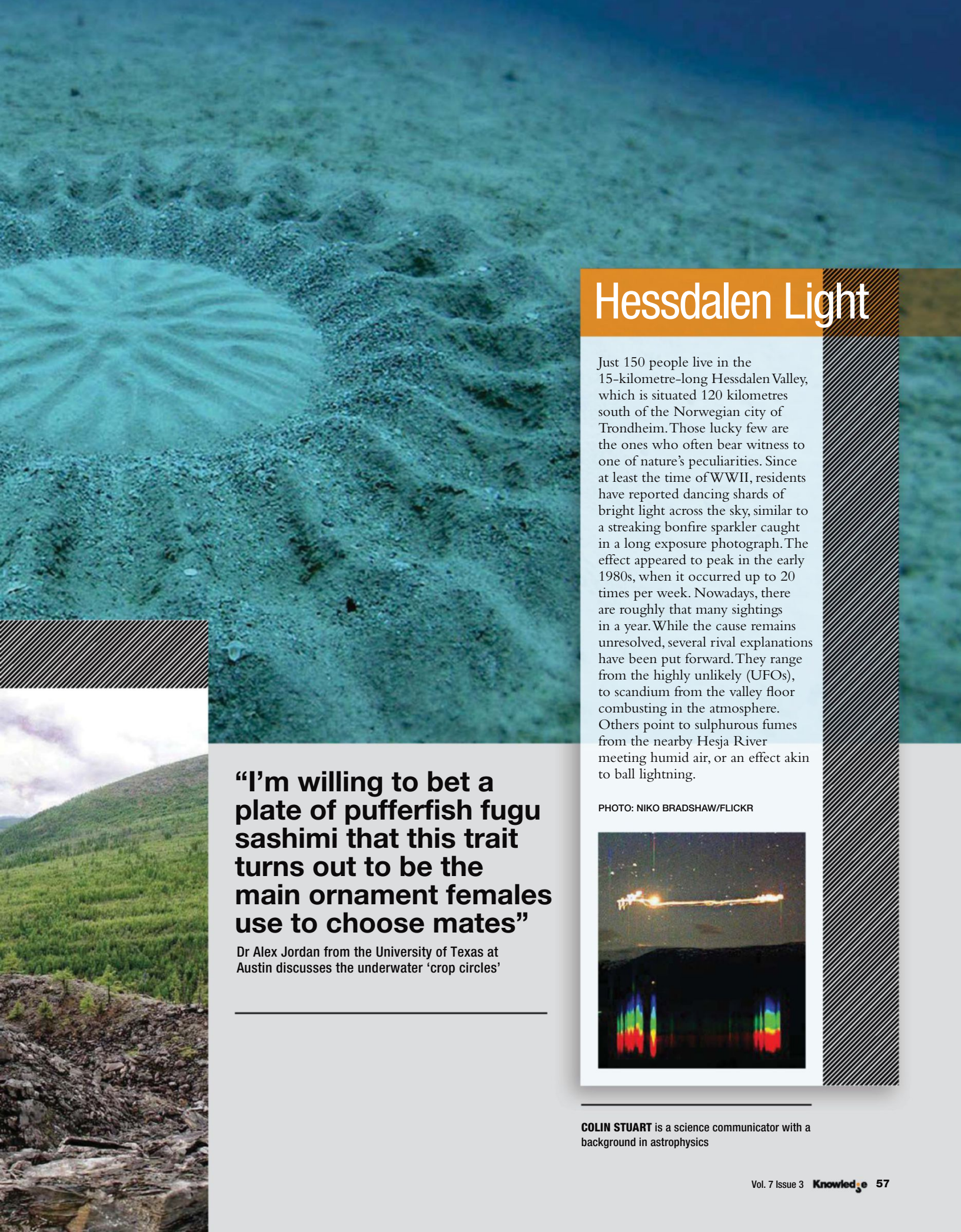
the seafloor material around. "I'm willing to bet a plate of pufferfish fugu sashimi [a dish that can kill you if not prepared correctly] that this trait turns out to be the main ornament females use to choose among potential mates," announces Dr Alex Jordan, a biologist at the University of Texas at Austin, US. Exactly which attributes the lady fish are looking for still remains a mystery. Watch the fish in action at <http://youtu.be/uuqYusAFQhE>

PHOTO: YOJI OOKATA/EXCLUSIVE PIX

Patomskiy Crater

The Earth's surface is covered in around 160 impact craters. These deep holes in the ground are caused by an object from space, such as an asteroid. At first glance, the Patomskiy crater – discovered in 1949 and situated in southeastern Siberia – seems like it should be on that list. Stretching 160 metres across, it has a central mound which resembles an egg nestled inside an eagle's nest. And yet there are severe doubts hanging over the impact hypothesis. "There is no evidence for its connection to a high-velocity impact. All such theories I've seen are pure speculation, made by people who have no clue about impact physics," says Dr Natalia Artemieva, from the Russian Academy of Science in Moscow. In 2013, half a tonne of material was removed from the site by helicopter. Perhaps analysing it will finally give up the crater's secrets.

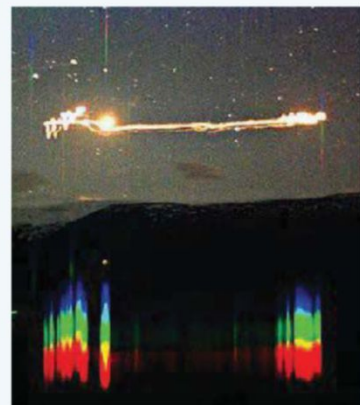
PHOTO: DMITRY DEMEZHKO



Hessdalen Light

Just 150 people live in the 15-kilometre-long Hessdalen Valley, which is situated 120 kilometres south of the Norwegian city of Trondheim. Those lucky few are the ones who often bear witness to one of nature's peculiarities. Since at least the time of WWII, residents have reported dancing shards of bright light across the sky, similar to a streaking bonfire sparkler caught in a long exposure photograph. The effect appeared to peak in the early 1980s, when it occurred up to 20 times per week. Nowadays, there are roughly that many sightings in a year. While the cause remains unresolved, several rival explanations have been put forward. They range from the highly unlikely (UFOs), to scandium from the valley floor combusting in the atmosphere. Others point to sulphurous fumes from the nearby Hesja River meeting humid air, or an effect akin to ball lightning.

PHOTO: NIKO BRADSHAW/FLICKR



“I’m willing to bet a plate of pufferfish fugu sashimi that this trait turns out to be the main ornament females use to choose mates”

Dr Alex Jordan from the University of Texas at Austin discusses the underwater ‘crop circles’

COLIN STUART is a science communicator with a background in astrophysics

OUR PLACE IN THE UNIVERSE

BY GILES SPARROW

It has taken some of science's greatest minds and centuries of research to establish, but we are finally confident of our position in the ever-expanding Universe

Where do we fit in? For more than 2,000 years, it's a question that astronomers have devoted a great deal of time trying to answer. Each new discovery has brought with it a further diminution of Earth and humanity's place in the cosmos. But at the same time, those discoveries have hugely widened our understanding of the Universe as a whole, and helped us establish the precarious position of life on Earth.

Most early 'cosmologies' owed more to mythology than science. But by the 6th Century BC, ancient Greek philosophers were developing non-mythological theories for the first time. The earliest of these to survive are from Anaximander of Miletus, who argued that Earth was not the centre of the Universe, but instead formed the top surface of a flattened cylinder, floating free in space.

A century later, Philolaus – a follower of the famous philosopher Pythagoras – imagined Earth as one of several planets in motion on circular orbits. However, it did not circle the Sun, but instead an unseen and mystical Central Fire. The Sun was a secondary fire (or perhaps a mirror) following its own orbit around

the centre. Philolaus's model was the first theory to suggest that the apparent motion of heavenly bodies derives, at least in part, from the movement of observers on Earth.

By the 4th Century BC, however, these ideas were undermined by an important realisation. If the Earth is in motion, then surely our view of the heavens should be subject to the same 'parallax' that affects other objects? In other words, just as a nearby tree shifts more rapidly against a distant forest when we change our observing position, shouldn't Earth's orbit through space cause celestial bodies to

shift their apparent positions back and forth over time?

For this reason, the great philosopher Aristotle argued that Earth must be the unmoving centre of the Universe. The Central Fire was discarded, and the Sun, Moon, planets and stars set on concentric crystalline spheres that carried them on circular paths around the Earth, which was now understood to be spherical. Aristotle's ideas would hold sway for almost two millennia, despite observations that challenged them.

In the 3rd Century BC, Aristarchus of Samos used geometry to show that the Sun is much larger than the Moon (and by extension, the Earth), and therefore much more distant. Doubting that a larger body would orbit a smaller one, he came up with the first Sun-centred (heliocentric) model of the Universe, in which Earth and all the other planets orbited the Sun on circular paths, with only the Moon orbiting Earth.

Nevertheless, the lack of observable parallax seemed like a fatal flaw in Aristarchus's model, and so Aristotle's 'geocentric' theory remained dominant. After Ptolemy of Alexandria added refinements in the



We now know that the Sun is at the centre of our Solar System, but great thinkers weren't always so sure





> IN A NUTSHELL

A supernova and a comet in the 16th Century helped astronomers to establish that the Earth rotated around the Sun, rather than the other way round. This paved the way for scientists to calculate the true scale of the Universe.

➔ 2nd Century AD, it would continue for another thousand years, and was treated as doctrine under the Roman Catholic Church.

In the 16th Century events conspired to break the geocentric stranglehold once and for all. Despite sophisticated mathematical models, Ptolemy's system remained incapable of tracking planetary movements over long spans of time. In the early 1500s, Polish priest Nicolaus Copernicus began to develop an alternative heliocentric system that seemed to do a better job.

He was not the first churchman to question the Earth-centred dogma, but his ideas emerged in the midst of a

religious Reformation that saw many long-held assumptions questioned for the first time. Copernicus only published the final version of his work *On The Revolutions Of The Heavenly Spheres* on his deathbed in 1543, but it was swiftly adopted across Protestant northern Europe.

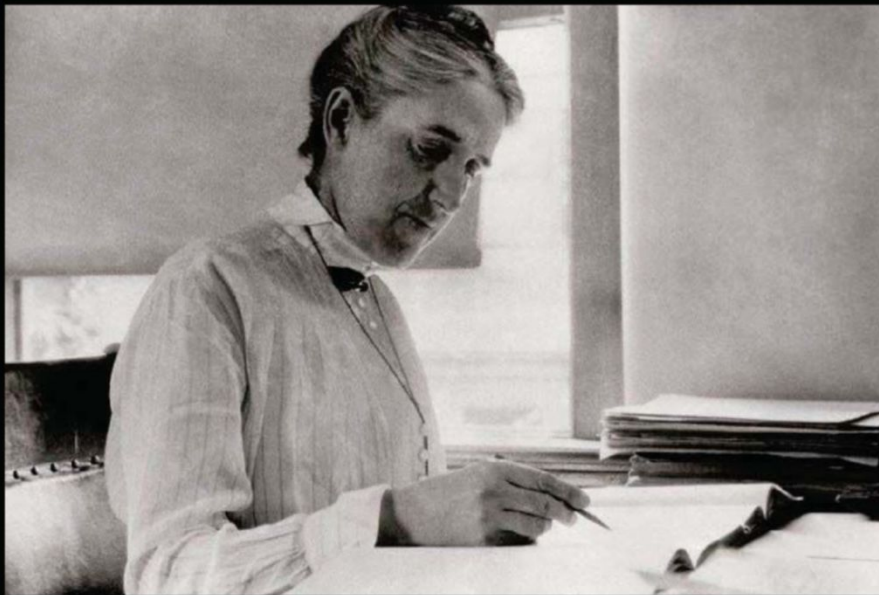
Two cosmic events soon helped the growth of heliocentric astronomy: first, a supernova (exploding star) erupted into view in the constellation of Cassiopeia in 1572. And then in 1577, a spectacular comet swept through Earth's skies. Danish astronomer Tycho Brahe observed both, showing by their lack of visible parallax that these objects lay

far beyond the Moon. The supernova challenged long-held beliefs about the unchangeability of the stars, while the comet was to prove the key to finally resolving the question of planetary orbits.

Using Tycho's observations, his assistant and collaborator Johannes Kepler worked out that the comet must have followed an elliptical orbit, and would therefore have passed through the supposed crystalline spheres supporting the other planets. Kepler went on to model the orbits of the planets themselves as elliptical paths around the Sun, and finally produced (from 1609) three laws of planetary motion that provided almost perfect predictions.

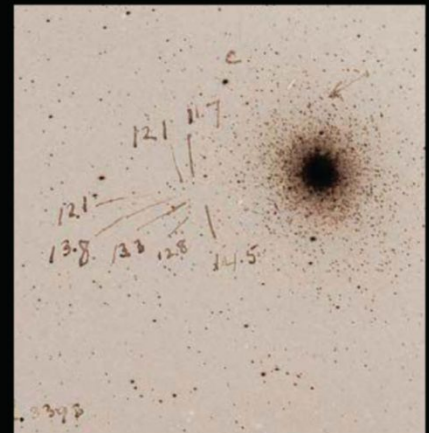
THE KEY DISCOVERY

Henrietta Swan Leavitt was the first to recognise a relationship between the brightness and period of Cepheid variables, allowing scientists to calculate distances in space



American astronomer Henrietta Swan Leavitt (1868–1921) was one of a team of women 'computers' who worked at the Harvard College Observatory from the 1890s under the directorship of Edward Charles Pickering. The so-called Harvard Computers analysed the huge quantity of astronomical data being gathered by photographic surveys, and Leavitt was assigned to study variable stars, cataloguing them into various classes according to the period and shape of their light fluctuations.

Leavitt was studying images of the Magellanic Clouds. These small, isolated star clouds situated in the southern hemisphere are satellite galaxies of the Milky Way. While analysing the pictures, she identified what seemed to be a relationship between the average apparent brightness of certain yellow stars and their period. She then made the reasonable assumption that the stars in each Magellanic Cloud were more or less the same distance from Earth. This then allowed her to treat the apparent brightness of the stars as a



Above: A portion of a plate with Leavitt's handwriting. The numbers relate to the brightnesses of stars

Left: Leavitt at work in the Harvard College Observatory as one of their 'computers'

representation of their relative luminosities, and revealed a clear period-luminosity relationship.

Since the variability cycle of these 'Cepheid variable' stars is quite distinctive, other astronomers were soon able to track down relatively nearby examples in the Milky Way, therefore allowing the relationship to be 'calibrated' to reveal a Cepheid's actual luminosity.

The Cepheids turned out to be highly luminous yellow supergiants, and provided the key to enable astronomers to measure extragalactic distances.

Finally, Earth had taken its true place as one of several planets in the Solar System. But it was not until 1671 that Italian astronomer Giovanni Domenico Cassini successfully measured the orbit of Mars and hence determined the true scale of interplanetary space, with tens of millions of kilometres, if not more, separating the planets.

Despite their breakthroughs, Copernicus and Kepler believed that all the 'fixed stars' lay at the same distance from Earth on the interior of a hollow cosmic sphere. One of the first people to doubt this was the British astronomer Thomas Digges, who in 1576 published an almanac popularising Copernican theory in English. He also argued for the existence of an infinite sea of stars scattered at random across space.

By chance, Kepler's discoveries had coincided with the invention of the telescope, and astronomers soon harnessed this new instrument to make measurements with unprecedented precision. Yet all signs of the stellar parallax predicted by the Copernican theory remained frustratingly elusive. As a result, some astronomers remained cautious about this new model of the Universe.

It was Isaac Newton who, in his 1687 *Principia*, settled matters once and for all. Not only did his laws of motion and gravitation provide an explanation for Kepler's laws, but he also made the first plausible estimate of a stellar distance. Based on the assumption that the brilliant star Sirius had the same intrinsic brightness as the Sun, he calculated its distance to be 800,000 times the Earth-Sun distance (12.6 light-years in modern terminology). Newton's figure overestimated Sirius's true distance by 45 per cent, but more vitally, it showed that the parallax of stars must be tiny, and measuring it would be a huge technological and observational challenge.

In fact, it was to be over 150 years before the challenge was finally met, by the German astronomer Friedrich Bessel. In 1838, Bessel announced he had measured the parallax of a faint star called 61 Cygni (an angle less than 1/5,500th the diameter of the full Moon). By this time, the Earth-Sun distance

CAST OF CHARACTERS

The great minds that helped shape our understanding of the Universe



Claudius Ptolemy (c.AD90–c.168) was a Greek-Egyptian astronomer who wrote the highly influential *Almagest*, modifying Aristotle's geocentric Universe with a complex system of epicycles. It helped explain why planets sometimes sped up, slowed down or even reversed their paths. The system proved so successful that the geocentric view survived until the Renaissance era.



Nicolaus Copernicus (1473–1543) was a Polish cleric who trained for the priesthood in Italy before returning to his native land. He was fascinated by astronomy but plagued by increasing doubts about the Ptolemaic system. He first outlined his heliocentric theory of the Universe in a small work circulated among friends and colleagues before 1514. Encouraged by its reception, he worked on a more complete heliocentric theory for the rest of his life.



Friedrich Bessel (1784–1846) was a German astronomer who made the first successful measurement of parallax for a nearby star in 1838. This required meticulous observation, and taking into account phenomena such as the aberration of starlight. Aberration is a slight change in the direction of all stars created by Earth's annual motion through space.



Harlow Shapley (1885–1972) dropped out of school and had set his sights on a career in journalism, but the Missouri native became captivated by astronomy. Although he played a pioneering role in using standard candles to pinpoint our location in the Milky Way, he later argued against galaxies beyond our own, and fiercely opposed Edwin Hubble's revolutionary discoveries.



Edwin Hubble (1889–1953) made a series of breakthroughs in the 1920s, using Cepheid variables to prove that distant nebulae were galaxies like our own. The US-born astronomer stated that the Universe extended for billions of light-years. He showed that the Universe is expanding in all directions – crucial evidence for the Big Bang theory.

TIMELINE

Copernicus introduced the Solar System with the Sun at its centre in the 1500s and turned astronomy on its head



Nicolaus Copernicus publishes his *On The Revolutions Of The Heavenly Spheres*, putting forward a detailed model of a Sun-centred Solar System as opposed to one with Earth at the centre.

1543

1609



German astronomer Johannes Kepler publishes his first two laws of planetary motion in a work called *Astronomia Nova*. By using elliptical rather than circular orbits, Kepler's laws accurately describe the motion of the planets in a heliocentric system.



Friedrich Bessel uses parallax to measure the distance to 61 Cygni, which is an orange-dwarf binary star some 10.3 light-years from Earth. This provides the first direct confirmation of the enormous scale of interstellar distances.

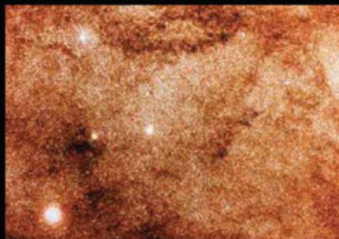
1838

1917



Harlow Shapley maps the distribution of globular star clusters around the Milky Way, showing that our Solar System lies many thousands of light-years from the galactic centre.

Edwin Hubble publishes the first evidence for Cepheid variables in the Andromeda Galaxy. This proves they are not part of the Milky Way – our Galaxy is just one in a possibly infinite Universe.



1924

➔ had been independently calculated, and so simple geometry allowed Bessel to find 61 Cygni's distance – 10.3 light-years in modern terminology.

Following Bessel's breakthrough, astronomers began to build a catalogue of stellar parallaxes, but progress was slow. By the end of the 19th Century just a few dozen were known with accuracy – it was only with the introduction of photographic surveys that parallax could be measured on a large scale.

Parallax was (and remains) the only way of directly measuring interstellar distances, but it is limited to relatively nearby stars with relatively large shifts. Fortunately, the information provided by direct measurements allowed astronomers to start working out physical properties of stars, such as their intrinsic brightness or luminosity. Contrary to Newton's premise, it soon became clear that stars varied hugely, and these variations would offer the next rung on the ladder of cosmic distance.

Comparing the luminosity of stars to the wavelength distribution of their light (crudely speaking, their colours) reveals clear patterns in their distribution that are shown in the famous 'Hertzprung-Russell diagram' of stars' properties. Astronomers can use it to estimate the rough distance to a star based on its 'spectral type' and its apparent brightness in our skies.

It soon became clear that certain stars display other properties that are very closely linked to their luminosity. Such stars are known as 'standard candles', because they can provide a light source of known luminosity that can be used to find cosmic distances far beyond the reach of parallax.

The first standard candles were used to map the scale of the Milky Way. Astronomers had long recognised that the distribution of stars around the sky was uneven, and that the Sun was probably embedded within a disc or flattened plane of stars. As early as 1781, William Herschel had attempted to map the Galaxy's shape, and pinpoint our place within it, by counting the number of stars in different directions. But, like Newton, he assumed that all stars were of roughly the same brightness and ended up with a flawed model in which the Sun lay near

NEED TO KNOW

These key terms will help you understand astronomy

1 LIGHT-YEAR

This is a common measure of astronomical distance. It is equivalent to the distance travelled by light, the fastest thing in the Universe, in the course of one Earth year. One light-year is equivalent to 9.5 trillion kilometres or 5.9 trillion miles.

2 PARALLAX

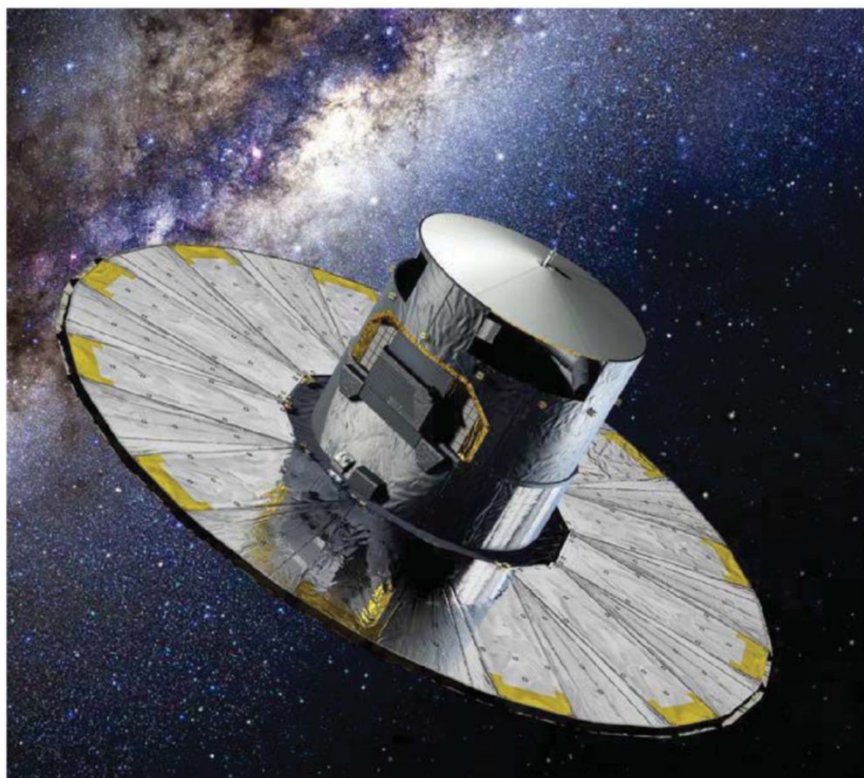
Diffraction is the bending of all waves by apertures and obstacles. The diffraction of light is not so obvious in ordinary life as its refraction, but it can be observed in the iridescent colours formed by a CD or DVD under visible light. The surface of these discs is ruled with very close lines, which form a diffraction grating.

3 STANDARD CANDLE

A standard candle is any class of astronomical object or event whose intrinsic luminosity is fixed, or can be calculated without prior knowledge of its distance from Earth. By comparing the luminosity of a standard candle with its apparent brightness as seen from Earth, astronomers can calculate its distance, and the distance of any larger system of which it forms a part.

the centre of the Galaxy.

It was not until 1908 that the American astronomer Henrietta Swan Leavitt recognised that a class of stars, known as Cepheid variables, had fluctuating brightness with a period linked to their intrinsic brightness (see *The Key Discovery*). Using these stars, American astronomer Harlow Shapley mapped the position of the Milky Way's globular clusters. These dense balls of stars lie above and below the Galaxy's central plane. He found that they appeared to be concentrated in orbit around a region tens of thousands of light-years from Earth in the direction of the constellation Sagittarius. He reasoned that this was probably the centre of our Galaxy, with



The European Space Agency's Gaia is compiling a 3D map of one billion astronomical objects in the Milky Way

the Sun demoted to being just one unremarkable star in the surrounding stellar disc.

Based on the measured size of the Milky Way, Shapley and many colleagues now assumed that our Galaxy effectively encompassed the entire Universe, while others argued that the faint 'spiral nebulae' seen in many parts of the sky were galaxies in their own right, viewed across a vast gulf of intergalactic space. This debate was settled in the mid-1920s by Edwin Hubble, who pinpointed Cepheid variables within several spiral nebulae. Based on their periods of variability, Hubble showed that they were intrinsically bright, appearing faint only because we see them over a distance of millions of light-years.

What was more, Hubble identified an important relationship between the distance of these galaxies and the properties of their light – the further away a galaxy is, the more its light is stretched or 'red shifted'. This relationship, known today as Hubble's Law, is a consequence of the general expansion of space in the aftermath of the Big Bang. Since the vast

majority of galaxies are far too distant to identify individual Cepheid variables within them, the law is often reversed to provide a rough estimate of a galaxy's distance based on its red shift.

Today, these two essential techniques – parallax and standard candles – still form the bedrock of much astronomical research. Advanced digital CCD cameras and satellite observatories such as the European Space Agency's Gaia (launched in 2013) are delivering parallax measurements with unprecedented accuracy across distances of tens of thousands of light-years. Meanwhile, deep-sky survey telescopes measuring the red shifts of thousands of individual galaxies are being used to build maps of the nearby Universe across many billions of light-years. Our place in the cosmos might seem increasingly insignificant, but at least we can be a lot more certain of where we stand.

GILES SPARROW is a science author. His latest book is *Hubble: Window On The Universe (Legacy Edition)*.

MARINE BIOLOGY

We know more about the surfaces of the Moon and Mars than our ocean floors. Marine biologist **Adrian Glover** sheds some light on the secrets of the deep

Q How much unknown biodiversity is there in our oceans?

Ever since we evolved complex thought and language, we have been documenting the biodiversity of Earth. The problem is that, where oceans are concerned, we have not been very good at it.

There are only about 230,000 described marine species, compared to 1.3 million terrestrial species. Does this mean that the oceans are lower in biodiversity compared to land? This seems a bit unlikely as we are certain that life and complex organisms evolved in the oceans. There has been a much longer period (several billion years, as opposed to a few hundred million) for species to diversify in the oceans. There is vastly more living space in the oceans than there is on land. So why the big difference in recorded biodiversity? The obvious answer is that over 90 per cent of the oceans are unvisited and unsampled by humans. There are thought to be hundreds of thousands – perhaps millions – of marine species that we have not found yet.

There is a further complication that biodiversity scientists often forget. Of the 36 branches of animal life, sometimes called 'phyla', all but two have representatives in the oceans. Of these 36 branches, 19 are found *only* in the oceans. So the question arises: is one deep branch of life, a peculiar marine worm for example, worth more in biodiversity terms than a thousand rainforest beetles?

The Swedish naturalist Carl Linnaeus once wrote: "If the names are unknown, knowledge of the things also perishes". In other words, the true value of inventories is not the list itself, but the knowledge that it represents. That peculiar marine worm, even just one species, may hold more unique biological knowledge than those thousand rainforest beetles. Not just the often-cited 'cure for cancer', but the key to an integrated view of the origin, diversity, function and resilience of the entire ecosystem of our oceans.

Q How are marine organisms distributed and connected?

All species are not distributed everywhere on the planet. While travelling across various islands and continents, 19th century naturalists such as Charles Darwin and Alfred Russel Wallace were inspired by dispersal barriers to conceptualise their evolutionary theories. Geographical barriers create reproductive isolation, therefore allowing species to evolve. But these early ideas were inspired mostly by observations made on land: the oceans were just the barriers. Scientists started to wonder, how are marine species distributed?

If we make the assumption that oceans are barriers to terrestrial species, and land is a barrier to oceanic species, then an obvious hypothesis presents itself. Given that all our oceans are connected to one another, marine species should have much broader distributions than terrestrial



Sloan's viperfish is found in several oceans, but not all marinelife has spread around the world

ones. For a long time, this has been the prevailing school of thought. Based on the morphology and anatomy of animals, marine biologists noted remarkably similar forms across whole ocean basins, and sometimes between them. For example, *Chauliodus sloani*, or Sloan's viperfish, is found in the Pacific, Atlantic, Indian and Mediterranean. Studies in marine laboratories showed that many ocean species release free-swimming larvae into the water column, which is an obvious mechanism to support the hypothesis of broad distribution. The larvae can simply swim up into ocean currents that can then disperse the animals for hundreds or thousands of kilometres. But like most general theories in biology, the hypothesis has not held up very well.

First, pioneering oceanographic studies of our deep oceans have



shown that the seafloor is not the flat homogeneous zone we once thought. The seabed is littered with numerous barriers such as seamounts, islands, ocean ridges, canyons, trenches, currents and complex water masses of different temperatures and salinities. Second, this early hypothesis missed something obvious. A geographic spot on the oceans has something that a spot on land does not: depth. Imagine taking samples of insects in a large rainforest tree, maybe 50m high. The species at the bottom are different to those at the top, with a gradual turnover as you pass up the tree. Now imagine that the tree is about 4,000m high – the average depth of the world's oceans. The vertical habitable space of the oceans is simply vast compared to land. Depth, with its dramatic changes in temperature and

food availability, is the most powerful dispersal barrier of all.

Evidence now shows that many marine species have limited distributions. For example, the common horse mussel is genetically different from one side of the Atlantic to the other. But coming up with a mechanism to explain both widespread and restricted species distributions is still eluding marine biologists. The integration of these genetic studies with traditional analysis of reproduction and natural history is the new grand challenge for scientists.

Q What can oceans tell us about animal evolution?

While Darwin developed his grand mechanism of evolution, stretching the

human mind to accept millions of years of constant species change, his advocate Ernst Haeckel drew the first pattern of this great process: the tree of life. But if you decide to draw such a tree, which species do you decide to include and how do you relate one animal to another?

In the post-Darwin world, it did not take very long for the anatomists and morphologists to realise that animals in the ocean had a far greater diversity of body plans than species found on the land. Jellyfish, corals, sponges, crabs, worms, snails, sea stars, sea squirts, fish... there is a bewildering array of life that enthuses and bemuses the beachgoing toddler and adult alike. From this morphological diversity, we see back in time to an explosion of marine life that took place hundreds of millions of years ago. These ocean creatures – familiar yet strange – form the heavy, lower branches of our tree. The terrestrial insects, reptiles, birds and mammals are merely treetop twigs.

We don't understand why these branches of ocean animals all appeared about 540 million years ago in the Cambrian period. But we know it happened rather suddenly. And here lies the problem: the ancient fossils of this period give us little clue as to which came first as everything appeared at more or less the same time.

Today, evolutionary biologists turn to the oceans, and the molecular biology of marine animal DNA, to find new clues to this remarkable transformation of our planet millions of years ago. By taking samples from intertidal rock pools, coral reefs, muddy bottoms, deep sea plains and volcanic hydrothermal vents, and comparing animals' DNA sequences – sometimes their entire genomes – scientists are making a start on an entirely new challenge in marine biology. In this way, they are resolving the nature of the origin of all animal life on our planet.

DR ADRIAN GLOVER is a research leader at the Natural History Museum in London and a specialist in the taxonomy, ecology and biodiversity of the deep sea.

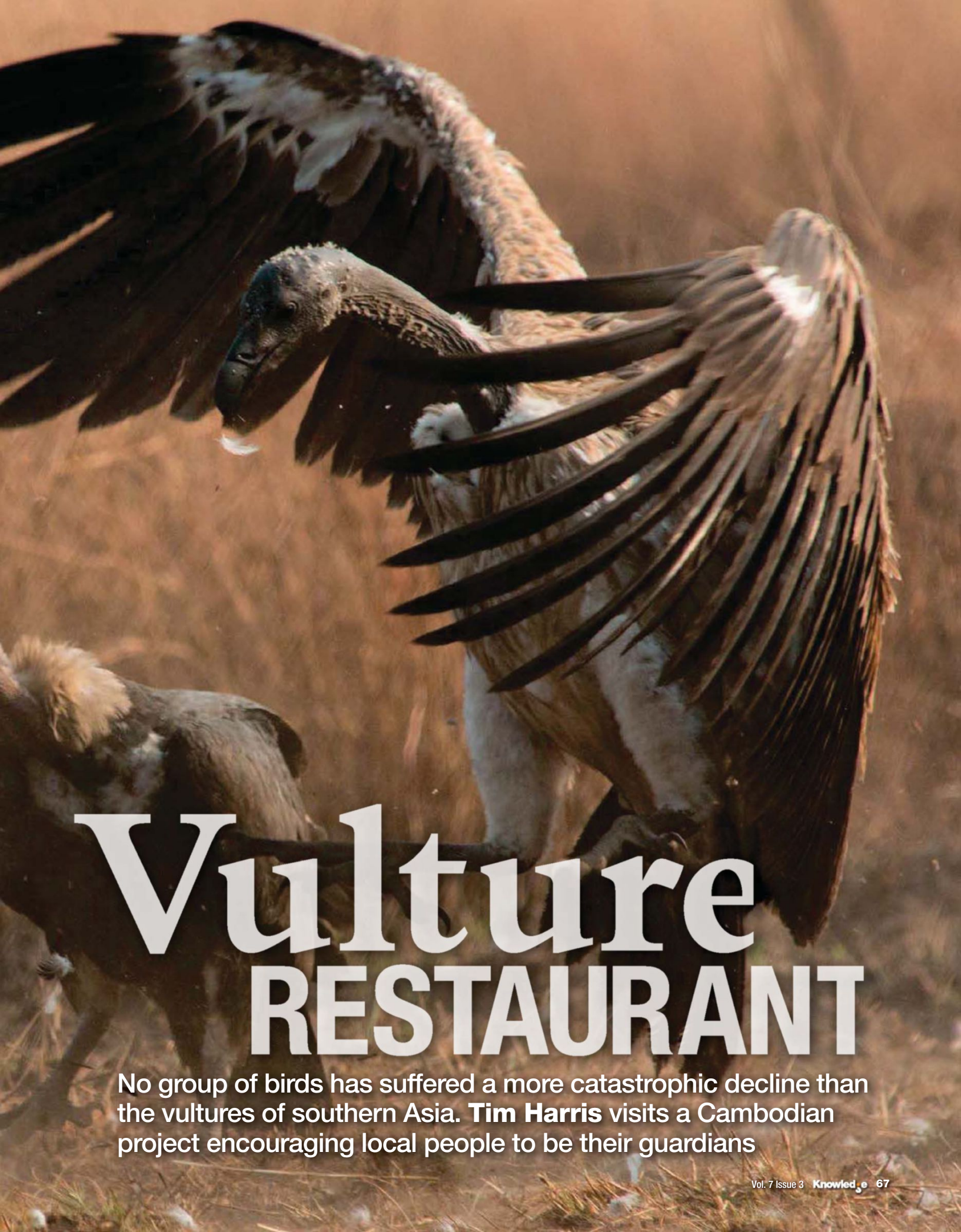




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Barrie Britton/BBC

A group of Critically
Endangered slender-billed
vultures fight over the
spoils on offer at a 'vulture
restaurant' in Cambodia



Vulture RESTAURANT

No group of birds has suffered a more catastrophic decline than the vultures of southern Asia. **Tim Harris** visits a Cambodian project encouraging local people to be their guardians



Above: slender-billed vultures make short work of a dead cow at the Veal Krous vulture restaurant. Right: red-headed vultures (this is an adult) also join the feast

It's still pitch-black as we leave the Veal Krous tented camp near the village of Dongphlet. As we walk into the clearing where the hide is located, Sophoan Sanh, our guide, signals for us to be quiet. "If we make too much noise, the vultures won't come for their breakfast," she says with a smile. Sophoan works for the Sam Veasna Center, the Wildlife Conservation Society (WCS) partner in Cambodia.

We heed the advice and take up our positions inside the hide, which is dug out of the ground so that we can see the action at eye-level. At around 6am the whoosh of a very large bird passes low overhead, followed by some flapping and an evil-sounding hiss. I risk parting the reedy screen a few centimetres and notice that the sky has lightened slightly, revealing the silhouettes of several vultures at the top of a tree. Much closer, just 30m away, several of these giants are already jostling with each other on the ground.

As the sun comes up over this corner of the northern plains of Cambodia, not far from the Laos border, the diners' identities are revealed. Most are Asian white-rumped vultures, but there are also a handful of red-headed vultures with their strangely perplexed expressions. The latter seem to spend most of their time standing around doing very little, but they are clearly one step up in the pecking order. Then come the slender-

billed vultures with their black, snake-like necks, perfect for pushing deep inside any dead animal.

Screams, hisses and the sound of wings flapping... this is the accompaniment to the end game as the bones of a cow are stripped of their last morsels of flesh.

Feeding time

Over the course of the next couple of hours I counted 51 white-rumped vultures. As recently as 1985 this magnificent species was described as being "possibly the most abundant large bird of prey in the world" – there may have been 40 million of these natural waste-disposal units in India alone. But now there are only a few thousand left. Has there been a more dramatic avian collapse since the demise of the passenger pigeon?

Yet at the Veal Krous vulture restaurant, the high drama of these scavenging birds ripping apart a carcass is still a frequent event. "One of my favourite memories here," says Sophoan, "is watching at peak feeding time as the three gangs of vultures competed with each other, when suddenly a golden jackal chased them away and took their place."

White-rumped vultures favour light woodland, often very close to human habitation, and roost and nest colonially in tall trees. "Like most vultures, the white-rumped is not fussy whether





the carrion it eats is fresh or putrid. And they'll devour any maggots, too," says Johnny Orn, the charismatic director of the Sam Veasna Center. "A group was once watched picking clean the bones of a bullock in 20 minutes flat."

Smaller numbers of slender-billed and red-headed vultures participated in the Veal Krous feast. The former is a species of dry, open country, usually away from villages, and joins communal roosts but is a solitary nester. "It is subordinate to white-rumped at carcasses, so seems to turn up in bigger numbers when its relatives are not around," says Johnny. The third member of the triumvirate, the red-headed, is classed by the Zoological Society of London as an EDGE species, which stands for 'Evolutionarily Distinct (with few close relatives) and Globally Endangered'. This species does not roost in large groups, and breeding pairs are strongly territorial.

During filming for BBC Two's documentary series *Wonders of the Monsoon*, cameraman Barrie Britton noticed that each vulture directs aggression almost exclusively at members of its own species. "The vultures would often wade through a melee of feeding birds just to pick a fight with a particular member of their own species," he says. "The red-headed ones seemed to change the brightness of their heads – they became a more vivid red when they were trying to intimidate rivals, while the slender-billed vultures had particularly impressive threat displays, bending their wings back to expose the white undersides."

Despite their behavioural differences, all three species have been virtually extirpated. It is now well documented that the collapse in vulture numbers on the Indian subcontinent –

down by a staggering 99 per cent since the mid-1990s – was brought about by the use of diclofenac, an anti-inflammatory drug administered to prolong the working lives of domestic animals (see box).

Describing the situation in India before and after the drug took its toll, environmentalist Tony Juniper commented on an RSPB blog: "Each year the vultures were eating about ►

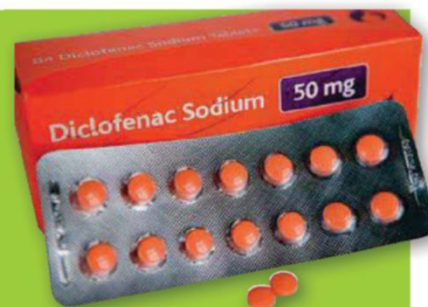
Top left: birders bring in revenue for poor local communities

Top right: special dug-out hides give an eye-level view. Above: the messy remains of a meal

Diclofenac A Killer Drug

Diclofenac is a non-steroidal anti-inflammatory drug developed in the 1970s as a treatment for arthritis and sprains in humans, but it has also been used as a veterinary medication. In the 1990s it began to be widely administered to sick livestock in India, Pakistan, Nepal and Bangladesh. However, when the animals died their carcasses retained the diclofenac, so that when vultures ate the flesh it caused kidney failure, gout and death.

The Indian government finally banned its veterinary use in 2006, and Pakistan, Nepal and Bangladesh followed suit. But five years after the Indian diclofenac ban it was



still available in 36 per cent of the country's veterinary pharmacies, and consignments meant for humans were illicitly diverted for use in cattle. Nevertheless vulture populations have started to recover in some areas. Meanwhile an alternative drug, meloxicam, has been found to be an effective painkiller in cattle and does not kill vultures.

Clockwise from top right: Neil Bowman x2; Alamy; Neil Bowman x2; Johnny Orn



The red-headed is a medium-sized vulture, but its wingspan is still over 2m

► 12 million tonnes of rotting flesh. With the vultures gone this became food for wild dogs. Their population rocketed and more dog bites and human rabies infections followed. This in turn led to an estimated 50,000 or so more deaths than would otherwise have been the case. The cost of this and other consequences on India's economy was (over a decade or so) put at an eye-watering US\$34 billion."

Cambodia's vulture populations had gone into freefall long before the advent of diclofenac in India, reflecting the collapse in the country's megafauna during decades of internal strife and war, and more efficient animal husbandry that produced a cleaner countryside. Shortly before the Indian vulture crash, Cambodia held only a small proportion of the world's multi-million-strong populations of Asian white-rumped, red-headed and slender-billed vultures. Yet that is no longer the case. In fact Cambodia stands almost alone in having vulture populations that have stabilised.

But it is not just an Asian problem. In Africa, too, diclofenac is hitting vultures hard, and they also face other serious threats on that continent. According to French ecologist Jean-Marc Thiollay, in the West African countries of Burkina Faso, Mali

and Niger there has been a 98 per cent decline in the population of four large vulture species in the space of just 35 years. Big falls have also been noted in East and Southern Africa. Mass poisoning and other persecution, habitat change and declines in large

ungulate populations have all played their part. Diclofenac has also been licensed for veterinary use in Spain and Italy, two of Europe's key countries for vultures.

Diclofenac may yet be banned in the EU, but in the meantime this gives vulture conservation in Cambodia, where the drug has never been an issue, some global significance. If these birds become extinct in places such as Dongphlet, what hope is there anywhere else?

Slow but steady recovery

The Cambodian Vulture Conservation Project was created in 2004 to co-ordinate the activities of several agencies, including BirdLife International's Cambodia Programme and the Sam Veasna Center. Seven vulture restaurants were established, the first of which was at Veal Krous, and an annual census programme was launched to monitor population trends of the three Critically Endangered species. A cow is slaughtered regularly at each restaurant to supplement the vultures' diet.

In June 2004 the census showed 42 red-headed, 90 Asian white-rumped and 25 slender-billed vultures attending the stations, a total of 157 birds. Six years later the respective figures were 46, 201 and 42, giving a combined total of 289. The restaurants were clearly working.

The researchers also monitored vulture nest sites and feeding stations, carried out health checks on the birds, and interviewed government officials, hunters and wildlife traders to collect data on threats. Satellite transmitters were attached to some birds to assess their ranging patterns. "Results from vulture censuses over the past several years have been encouraging, with new nests recorded and even

"The village benefits financially from visitors who watch, photograph or film the vultures"

Cambodia's clean-up crew

Three threatened species visit the vulture restaurants...



Asian white-rumped vulture
Gyps bengalensis

Range South and South-East Asia, from Pakistan east to Vietnam

Population Formerly several million; estimated 3,500–15,000 today

Population decline Over 99.9 per cent since the mid-1990s

Status Critically Endangered



Red-headed vulture
Sarcogyps calvus

Range South and South-East Asia, from Pakistan east to Vietnam

Population Formerly hundreds of thousands; estimated 3,500–15,000 today

Population decline In India, 91 per cent between mid-1990s and 2003

Status Critically Endangered



Slender-billed vulture
Gyps tenuirostris

Range South and South-East Asia, from India east to Cambodia

Former population Formerly hundreds of thousands; estimated 1,500–3,750 today

Population decline In India and Nepal, 97 per cent between mid-1990s and 2007

Status Critically Endangered

IBIS Rice How farming can help to save a giant

An innovative agricultural project in Cambodia has created the Ibis Rice brand, giving a boost to the threatened giant ibis (below), the largest member of its family and sole representative of its genus. Numbers of the giant ibis crashed as a result of hunting, deforestation and the drainage of trapengs (seasonal pools) where it feeds – with a global population of as few as 350 individuals, it is now classed as Critically Endangered.

The surviving birds are today concentrated on the northern plains of Cambodia, particularly around the Khmer village of Tmatboey. Here villagers have come to see themselves as stewards of the birds' future, and are working with the Wildlife Conservation Society and the Sam Veasna Center to grow Ibis Rice, produced locally without draining the seasonal pools, cutting down trees or hunting the ibises. Villagers earn extra money by hosting visiting birdwatchers keen to see this global rarity.



An adult and two sub-adult red-headed vultures. Aggression at carcasses is mostly between members of the same species

population increases," says WCS biologist Tom Clements. "With continued investment, these critical populations can survive and grow."

Even better, the Veal Krous restaurant has become an integral part of the life of the Dongphlet community. "Conservation is important for our next generation," says Prak Bunthy, a deputy chief of the forest community. The initiative works because the Sam Veasna Center ensures that the village benefits financially from any visitors who come to watch, photograph or film the vultures.

Community benefits

"There are two ways that we reward the community," explains Johnny Orn. "Firstly we pay the people who cook for tourists and provide tents, as well as the guides who take visitors to the restaurant and the rangers who protect vulture nests. Secondly we collect US\$30 from every tourist each time they visit the restaurant. We bank the fees until there is a meeting with all of the villagers and they decide the infrastructure to invest in."

The Sam Veasna Center pays US\$450 for every cow that is slaughtered. Since the project started in 2008, at least US\$100,000 has been spent on the Dongphlet community, and about US\$40,000 of that has come from ecotourism organised by the centre. Everyone benefits, and the Sam Veasna Center is already applying the ethos of community involvement elsewhere in Cambodia, for example by taking birders to see rare Bengal floricans.

No one has any illusions that it is going to be an easy task to nurture vulture populations back to sustainability. And there have been real setbacks. Vultures have died after ingesting poison targeted at other species, and there have been cases of deliberate attacks with guns and slingshots. But the local community seems to be totally committed. Prak says, proudly, "We, the villagers of Dongphlet, are determined to protect these amazing birds."

"Diclofenac has been licensed for animal use in Spain and Italy, two of Europe's key vulture countries for vultures"

Below left: villagers vote on how to invest vulture restaurant fees. Below: a white-rumped vulture warns a rival vulture to back off



TIM HARRIS is a birder who visited Cambodia's vulture restaurants in 2013. His most recent book is *RSPB Migration Hotspots* (Bloomsbury).

Clockwise from bottom: Johnny Orn; Martin Hale/FLPA; Neil Bowman x2

HOLLYWOOD SCIENCE

Separating science fact from movie fiction

Tornadoes in Into The Storm

Tornadoes are one of the most destructive forces of nature. In their wake, they can leave a trail of devastation that's worse than the aftermath of toddler's birthday party. The video release of tornado-tastic disaster flick *Into The Storm*, in which multiple columns of wind batter buildings, suck people into the sky, and flip vehicles like burgers. But how likely are you to be totalled by a twister?

Unsurprisingly, it depends where you live. America, where the film is set, experiences around 1,000 tornadoes per year, of which five to 10 measure top whack on the tornado intensity or 'Fujita' scale. With their columns of air rotating at speeds of up to 515km/h, these can raze buildings and turn towns to rubble. Vehicles are damaged, not by being tossed into the air, but from tumbling across the

"In 2011, an Alabama schoolboy was whipped 9m (30ft) into the sky by a tornado"

ground and being pummelled by debris. And once in a while, as in the film, a single weather system spawns multiple twisters to create something truly terrifying. On 25 to 28 April 2011, 324 people lost their lives when an outbreak of 355 tornadoes swept across the US. In the same year, an Alabama schoolboy was whipped 9m into the sky by a tornado that ripped the roof from his house. He survived with cuts and bruises – and quite a story to share at playtime.

In the US, tornadoes tend to form when warm, moist air moves up into an already spinning parent storm or 'supercell', and a column of less buoyant air sinks down. "The tornado forms near the intersection of the up and downdrafts," says meteorologist David Schultz from the University of Manchester. Doppler radar can be used to detect the rotating air in the supercell some 10-20 minutes before the tornado forms, giving national weather services a chance to issue warnings. The tornado then tends to move in a predictable direction (normally

SW-NE in the US) at speeds of around 80km/h; they rarely do the rapid U-turns seen in movies. "You can outrun one on a straight road, no problem," says Schultz. If you're still driving that 20 year old jalopy though, we'd suggest not trying.

I, however, can feel smug. In the UK, there are just a few dozen tornadoes per year, and like our burgers and our belts, they tend to be smaller than their US counterparts. A key difference, says Schultz, is that British tornadoes generally come from linear storms – cold fronts that move down the country – rather than from supercells. No one is quite sure how this happens, but it's good to know that the only twister I'm likely to encounter is the one played at parties with sherry-fuelled friends or relatives.

HELEN PILCHER is a science writer and comedian. You can follow her on Twitter: @Helenpilcher1





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PICK YOUR DIET

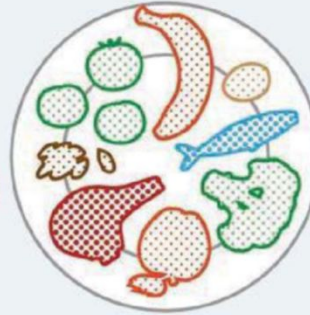
For every inch you've added to your gut, a fad diet promises to help you shed it. **Anna Kibbey** chews over the science...



Cabbage Soup



Vegan



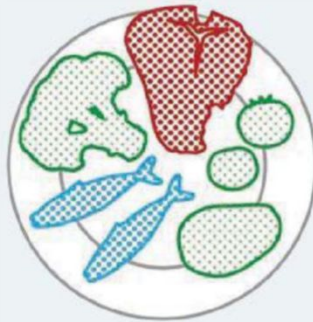
Raw Food



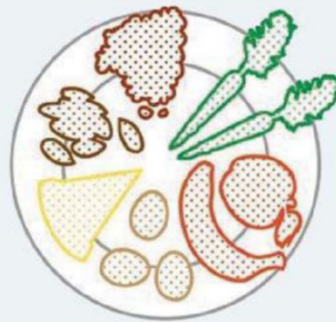
Pescetarian



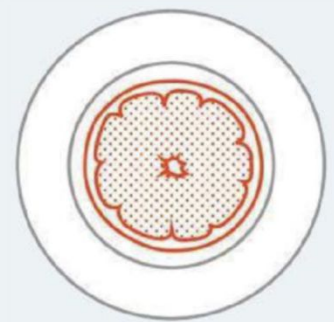
Piscivore



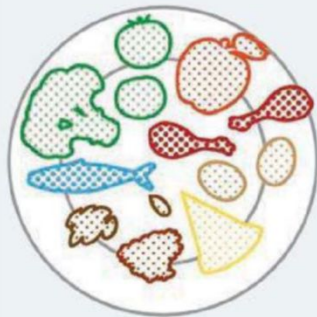
South Beach



Vegetarian



Grapefruit



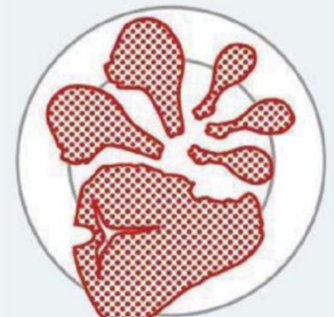
Omnivore



Atkins



Paleo



Carnivore

KEY

	Vegetable
	Fruit
	Meat
	Fish

	Dairy
	Eggs
	Nuts & Seeds
	Pulses & Grains

The bonhomie of the festive season feasting will soon be replaced with a fog of post-festive recriminations and a long, hard look in the mirror. In the cold light of March, chances are you might be feeling less than happy

with the shape of the person looking back at you. But salvation is only a Google search away in the comely form of the latest diet plan, featuring lithe 30-somethings brandishing forkfuls of grapefruit, or mums holding up enormous



➔ pairs of their old trousers. Not only will this diet help you slide effortlessly back into your skinny jeans, it'll also brighten your skin, reduce your risk of cardiovascular disease and stop diabetes in its tracks. But are the *diets du jour* really as perfect as they claim to be? And are there any facts behind the fads?

Celebrity endorsement goes a long way to turning a diet idea into a diet trend, with or without scientific evidence. Take the Raw Food plan, beloved – allegedly – of the likes of Uma Thurman and Demi Moore. Heating your food destroys the nutrients and natural enzymes, which aid digestion and protect you from chronic disease, say raw food fanatics. So cooking food, in effect, 'kills' it. Followers of the diet make sure that around 75 per cent of their daily diet is made up of plant-based foods that haven't been heated above 46°C. The diet purports to boost everything from your immune system to your memory, clearing up headaches and allergies, arthritis, diabetes and so on.

On paper, it makes perfect sense. When thrust into the fiery furnace of scientific scrutiny, however, the diet goes up in smoke. "The Raw Food diet has the least scientific evidence or reasoning behind it," says Dr Scott Harding, lecturer in nutritional sciences at King's College London. "There is no way that eating raw food specifically improves people's antioxidant capacity or directly reduces their risk of developing chronic diseases."

Scientific rationale might have made short work of raw food, but researchers have engaged more enthusiastically with other fashionable eating plans. Take the paleo diet, the most Googled eating plan of them all. By basing the diet on the supposed eating habits of our lean, disease-free hunter-gatherer ancestors, this plan promises weight loss, as well as a reduced risk of diabetes, heart disease and cancer. The rules: no processed food, sugar, dairy, grains or legumes, just foods that can be hunted, fished or gathered (eggs, nuts, seeds, fruits, vegetables, herbs, spices). It's a compelling elevator pitch, but does the science stack up?

"There is no way that eating raw food directly reduces their risk of developing chronic diseases"

Dr Scott Harding, lecturer in nutritional sciences at King's College London

Paleo's flaw is in its premise. As critics have pointed out, our digestive systems and food have evolved significantly in the past 10 millennia. Contrary to popular interpretations of caveman's carnivorous and low-carb eating habits, evolutionary research suggests that our earlier ancestors feasted frequently on nuts, seeds, fruits and veggies rather than meat and fish. Stone Age humans



Participants in a 2010 study by Unilever still felt full three hours after eating a meal like the one above. This is a 'true' paleolithic diet, with plenty of nuts and veg

Plenty of fruits and vegetables should be included in your diet and will help you feel full



Dr Mark Berry says that our ancestors ate 20 plant-based foods every day

would have eaten around 20 different types of plant-based foods a day, says Dr Mark Berry, senior research and development manager at Unilever, who led a 2010 study into the paleolithic diet.

“It has been interpreted as a low carb, no-grain diet – similar to Atkins – but the publicised form isn’t quite how it was,” says registered nutritionist and dietitian Sue Baic, co-author of *Nutrition For Dummies*. “Actually, the paleo diets had quite a lot of plant foods. The diets are characterised by low energy density, high fibre and large amounts of bioactive plant polyphenols.” It’s this broad spectrum of phytonutrients (compounds found in plants) that holds the key to its success.

Fill up on fruit

In Dr Berry’s study, volunteers were served either a plate of fish and rice with one portion of veg and one of fruit – a ‘healthy’ modern-day meal – or a paleo-inspired meal of fish and a variety of different fruits, vegetables, nuts and mushrooms. Those who consumed the paleo meal felt much fuller three hours after eating. They also had significantly higher levels of PYY, which is the hormone that tells us we’ve had



Some followers of the paleo diet eat their meat raw – we don’t recommend trying this



We’ve analysed the evidence and scoured the science to develop an easy healthy eating plan to help you safely shed those unwanted kilograms...



7.30AM – Breakfast

Porridge with milk and berries (270kcal)

The National Weight Control Registry stated that the most successful long-term weight-loss maintainers cite regular breakfast as one of the key strategies.

10.30am – Snack (Optional)

Oatcakes spread with either peanut butter or hummus (160kcal)

Snacks that contain protein keep you fuller for longer, according to research from the School of Medicine at Missouri University.



1PM – Lunch

Tuna, olive oil dressing and a rainbow mix of vegetables of your choice (400kcal)

The University of Illinois found that those who eat more protein and less carbs find it easier to stick to their diets. Protein can also boost calorie burn, the study authors say.

3PM – Snack (Optional)

Handful of fruit, nuts and seeds (160kcal)

Eating something small and healthy every three hours was one of the most popular strategies of successful dieters in 2012’s National Mindless Eating Challenge.



7.30PM – Dinner

Starter: vegetable broth (60kcal)

Research from Penn State University in 2007 showed that soup before a meal reduces calorie intake by 20 per cent.

Main course: grilled chicken, quinoa and vegetables (600kcal)

Iowa State University research published in June 2014 in the *Journal Of The Academy Of Nutrition And Dietetics* found that when participants increased their chewing by 100 per cent, they consumed 112 fewer calories over the course of a meal.

FACT VS FAD

10 tell-tale signs that your chosen diet may not be all it's cracked up to be...

- 1 It promises a magic bullet to solve a problem without having to change your lifestyle in any way.
- 2 It promises rapid weight loss of more than 0.9kg of body fat each week.
- 3 It recommends the magical fat-burning properties of particular foodstuffs.
- 4 It promotes the avoidance or severe limitation of an entire food group, such as wheat or dairy. It then suggests large and/or expensive doses of vitamin and mineral supplements as a replacement for these foods.
- 5 It promotes eating mainly one type of food for all meals such as cabbage soup, Mars bars or eggs, or avoiding all cooked foods.
- 6 It recommends eating foods only in particular combinations based on your genetic type or blood group.
- 7 It recommends avoiding foods in certain combinations, such as eating fruit with meals.
- 8 The only supporting evidence offered is from a celebrity with a personal success story to tell.
- 9 It suggests that being overweight is related to a food allergy or a yeast infection.
- 10 If it sounds too good to be true, it probably is!

➔ enough to eat. While paleo isn't perfect, it does have valuable elements. "Super-sizing fruit and veg will fill you up," says Baic. "And very concentrated high-energy density foods that are high in fat and sugar need to be kept more as treats."

The other problem with paleo in its popularised form, says Baic, is that cutting out a food group, like grains, doesn't just unbalance your diet, it also makes it more difficult to sustain. "Low-carb diets and the so-called paleo are difficult to follow, while macrobiotic and raw diets just aren't sensible," she says. Your diet needs to be realistic if it's going to be successful. If it's realistic, it's likely to be more sustainable, and sustainability is a cornerstone of the 'perfect' diet plan. "The majority of evidence shows that most diet approaches work if people can follow them," says Baic.

Not so fast

Enter the 5:2 diet, which offers five days of normal eating "with little thought to calorie control" to every two days of near fasting, when you eat a quarter of your recommended daily calorie quote. This works out as 500 calories for women and 600 for men. Not only is the concept of 5:2 easy to grasp, it's also a less punishing regime to follow. Got a client dinner or a birthday lunch? No problem, you won't fall off the wagon. "From this point of view, the 5:2 diet is very good," says Baic. "There's good evidence to support it. It's not for everyone – say, if you've got a history of eating disorders or diabetes, or you're pregnant or breastfeeding – but generally it fits in with modern life. Psychologically, you know you're not depriving yourself every day."

However, research published in *The American Journal Of Clinical Nutrition* in July 2005 showed that for long-term weight-loss success, a consistent diet approach was more successful. Participants who reported a consistent diet across the week were 1.5 times more likely to maintain their weight within 2.2kg over the next year than those who dieted more strictly on weekdays. So it might work in the short term, but consistency, it seems, will keep you in the healthy eating game for the long haul. And a 2014 review by researchers at the University of Illinois found that daily calorie restriction is still a more effective means of losing weight than fasting.

The key to the perfect weight-loss diet is calorie restriction. "The only way a diet will work is if you're in calorie deficit," explains Baic. "Reduce calorie intake below energy



On the 5:2 diet, calories are restricted for two days each week



Dr Brian Wansink's studies found that mindful eating can lead to diet success



expenditure and your diet will be successful.” Once you’ve grasped this, it’s a mental game.

Mindfulness in weight loss is a growing area of research. It has long been the theory behind supported diet plans, which encourage followers to attend local groups and weigh-ins. According to Baic, these have impressive success rates. “Diet programmes like Weight Watchers, Slimming World and Rosemary Conley all give really good, evidence-based advice and offer support, so there’s a psychological side to it as well,” she says.

In 2012, Dr Brian Wansink and researchers at Cornell University launched the National Mindless Eating Challenge, which examined the difference in behaviour of successful and unsuccessful dieters. Mindfulness, or being aware of what you’re eating, was a key factor in the success stories. Keep kitchen counters clear of unhealthy foods, serve food on plates, never eat from the packet and put down your utensils between mouthfuls to slow your eating.

Solid science

So, while the Raw Food, paleo and 5:2 diets certainly aren’t perfect ways of losing

“The majority of evidence shows that most diet approaches work if people can follow them”

Sue Baic, nutritionist, dietitian and author of *Nutrition For Dummies*

weight, they do offer some sound, evidence-based principles. “These diets generally have an exaggerated approach to established concepts,” says Dr Harding. “Both the paleo and Raw Food diets tend to be higher in plant-based foods, have much higher fibre than a typical Western diet and have lower saturated fats and added sugars. Increasing dietary fibre intakes to 25–30g per day, reducing saturated fat and added sugar intakes and increasing fruit and veg consumption are standard 30-year-old dietary

recommendations in most developed countries. The 5:2 is approaching caloric restriction with a long term view versus a daily focus – over a 14-day period you reduce your total calories by approximately 15–20 per cent without feeling as though you have to sacrifice daily.”

So, if you want to shift those festive kilograms, don’t buy in to a diet plan because Jennifer Aniston does it, or you just like the sound of eating like a caveman. You’re more likely to end up with chronic halitosis and a powerful urge to gobble up the rejects in the Christmas chocolate selection pack than achieve the body of your dreams. The simple scientific answer is this: restrict your intake of food by 500 calories a day and find a way to do this that you can sustain, whether that’s attending a regular support group or re-jigging your intake à la 5:2. Create a diet that includes protein, carbohydrates and as many fruit and vegetables as you can handle – have a look at the recommended on p75 – and you’ll be back into your jeans or dress in a couple of months.

ANNA KIBBEY is a freelance journalist with a particular interest in health. She also writes for *Men’s Health* magazine





CHARGING UP

Electric cars are going mainstream with the help of some nifty technology. Daniel Bennett tests four battery-powered motors

Batteries haven't got the best reputation. Whether they're in our cameras, phones or TV remote they never seem to last quite long enough. But as far as cars are concerned, battery power might be turning a corner. A new Formula E championship, backed by big companies and celebrities, is about

to race through some of the world's biggest cities and electric charging stations are now springing up in city centres and motorway service stations across the UK.

It all means that electric cars are increasingly becoming a more realistic proposition for drivers. On average they manage around 130km between

charges – the average UK car trip is just 11km (7 miles) long, according to the Department for Transport.

Meanwhile, batteries are improving, with some boasting charge times as short as 30 minutes. So, putting range concerns aside, we looked at four electric models to see which is leading the pack.



Renault Zoe



The Zoe is exactly what you'd expect the French take on the small car of the future to be like. It's cute. Inside, every corner has been rounded off, every panel coated in white or grey paint, and almost every button or dial has been replaced by a screen. It sort of feels like you're driving an iPod – and I mean that as a compliment. Even the chairs are emblazoned with markings reminiscent of the USB symbol.

Take it into the city centre and it's a little oasis of calm. In the midst of cars and lorries puffing out fumes and heat, the Zoe feels like an eminently sensible place to be. It's rapid too. From 0–30mph (0–50km/h) it seems to move quicker than the other cars here, squeezing into gaps

and darting around traffic with ease. The Zoe emits a faint hum plucked right out of a science-fiction film, which helps alert pedestrians who may otherwise step into the road without looking. Electric cars make next to no sound at low speeds, so the hum lets everyone know it's there.

The most attractive feature of the Zoe is its price. It's the cheapest car here, although it doesn't feel like a budget choice. However, you do have to lease the car's battery from Renault for a fee. This might sting in the long run, but it does mean your battery is guaranteed for life. The Zoe is the most accessible option if you're thinking of going electric.

Nissan Leaf

When it first hit the roads around four years ago, the Nissan Leaf was a pioneer – one of the first mass-produced electric cars. This has made it something of a standard to be judged by. Sadly today it doesn't feel as futuristic as it once did next to the interiors of the i3 and the Zoe. What it lacks in pizzazz, though, it makes up for in practicality. It's much bigger than the other cars and offers heaps of space in the back and in the boot for when you've got a family and their luggage in tow. The built-in multimedia and sat-nav system is also easy to use. There's no hair-pulling while you wait for it to catch up with what you want it to do.

For such a large car the battery power makes it feel

spritely, especially when you need to quickly jump into a gap in the traffic. Of the four it also seems to do the best job of cutting out the noise around you. Pair that with the car's soft suspension and you have a remarkably serene car to drive.

All electric cars start losing miles from their range when you turn the air conditioning on, but the Leaf is the only car in this review to present a solution to that problem. After listening to driver feedback over the last few years, Nissan introduced a small solar panel on the roof. So while the Leaf might not be as groundbreaking as it once was, it's evolved into something that makes all-electric driving a much more realistic proposition.



BMW i3



On the road, the i3 looks and feels like you've driven a concept car straight out of an International Motor Show. Step inside and the story is much the same. The i3 has been built from the ground up to be an electric car so there's no transmission tunnel hogging the space between passengers. Since the chassis is so strong, there's also no column between the front and rear seat. This opens the car up to make it feel like there's more space than any of the other cars.

On the whole, the i3 makes a pretty strong argument for what cars of the future might look like. For a start, it's the first mass-production car to be built from carbon fibre reinforced plastic. While this does add cost, it saves on weight, giving you

much better mileage. Inside the i3 is panelled with grey recycled plastics and textiles, which on paper might not sound appealing, but it looks great.

The battery, which goes 130-160km in one charge, can be complemented with a 'range extender' – a small petrol generator in the front that will send extra electricity to the battery should you need to go further. It'll park itself, drive itself down the motorway and stop itself if it thinks you're heading for a high-speed collision. It's quick too, powerful enough to leap off the lights and streamlined enough to hit the motorway without eating up too much range. The i3 is something special indeed.

VW E-Up!

Volkswagen has taken the sensible approach to building electric cars. Rather than build a new vehicle from scratch, it's decided to go with a formula that it knows works, adapting existing cars to take on electric motors. This way you can opt for battery power in your next Up or Golf, just as you might chose between petrol or diesel. It's a cheaper way of building electric cars, which makes repairs and servicing less hassle. This does mean, however, that on the inside the e-up! isn't as dazzling as the other cars here. In fact if you've ever stepped into a VW it's instantly familiar, which might appeal to some while leaving others longing for an interior that's a bit more futuristic.

The e-up! is not without its charms though. It easily has the best driving position of all the cars here – you can confidently see all corners of the car without having to contort yourself around the seat.

All four cars soak up some of the kinetic energy from the car when your foot is not on the accelerator to charge the battery, but the e-up! gives you five different levels of braking so that you can match it to your driving style. The multimedia and sat-nav is packaged in a plug-in Garmin sat-nav device called Maps & More, which works well but isn't as attractive as the other systems.

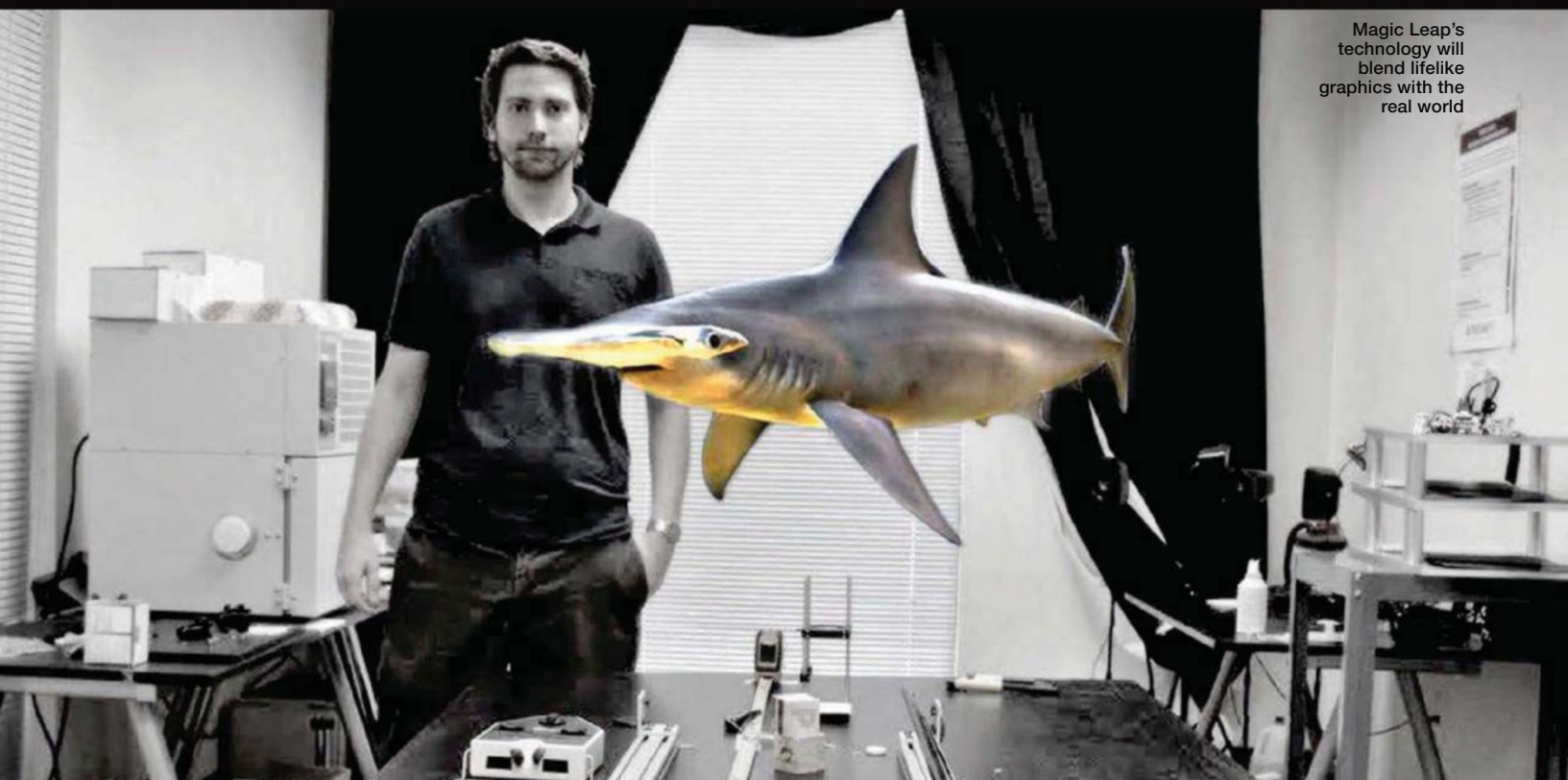
The e-up! is hard to fault, but if you're looking for some wow factor for switching to electric then this might not be the motor for you.



The Future Of Gadgets

TECHHUB

Edited by **Daniel Bennett**



Magic Leap's technology will blend lifelike graphics with the real world

On The Horizon

Magic Leap

Augmented reality technology

Magicleap.com

words: **JOE MINIHANE**

Augmented reality (AR) finally looks set to go mainstream. Google Glass and Sony's SmartEyeGlass have pointed the way forward and now a company called Magic Leap is set to take this exciting technology to the next level. In future, you'll pull on a pair of glasses and gain a new perspective, with information overlaid on your view.

"When we think about AR, what comes to mind is going

to a party or a business meeting and getting the names and information about everyone you can see superimposed on your vision. Or you could get GPS navigation instructions directly streamed on your retina. You could also think about playing computer games that are seamlessly integrated into the real world, calling your family and friends on Skype but seeing them in your room,"

explains Gordon Wetzstein, an assistant professor in electrical engineering at Stanford University.

Patent filings show that Magic Leap is working on a headset that will layer 3D images over an everyday scene. Using so-called 'light field technology', it will be able to deliver more realistic views compared to the likes of Google Glass, with varying depths of field.

"Light field technology allows you to show virtual content at



Magic Leap mimics light bouncing off objects, potentially allowing you to see seahorses dancing in your living room

any depth, which allows you to focus your eyes at the correct depth in the scene,” explains Wetzstein, who has a PhD in light fields from MIT.

“A light field is a little bit like a hologram. It reproduces the physical distribution of light rays in a manner that is much closer to what we would see in the real world, so you can expect better and more comfortable AR in a smaller device,” he adds.

By mimicking the light field created when light bounces off a real object and reaches your eyes, Magic Leap could make virtual objects indistinguishable from physical ones. You could explore a virtual seahorse from every angle, for example, and the only clue that it wasn’t real would be its lack of a proper shadow.

Magic Leap may end up as a rival to virtual reality headsets like the Facebook-owned Oculus Rift and Sony’s Project Morpheus. But it could also have more everyday uses. Magic Leap is hiring experts in Android development and 3D gaming, suggesting that you might use it via apps on your smartphone or tablet.

To build its technology, Magic Leap is going to need experts in computer vision

(CV) algorithms. Fortunately, it has the world’s leading CV expert, Gary Bradski. Bradski created a library that’s depended on by most CV developers today.

It’s probably because of Bradski’s involvement that the US-based startup company has already attracted \$542 million in funding, from Google and smartphone chip maker Qualcomm among others.

Yet for all the money and hype emerging from Silicon Valley, very little is known about Magic Leap. Its founders are keeping their cards close to their chests, refusing interview requests and not showing off any prototypes.

So what will it be like? “Where I see this going is a fully integrated camera and display, perhaps in your regular glasses. You won’t even notice it’s there,” speculates Wetzstein. “It’ll give you very different experiences from what we know today.”

It is a sci-fi vision of the future, but one which science, not to mention Google, believes is increasingly likely.

JOE MINIHANE is a technology writer. He tweets from @joeminihane

Techometer

What’s Hot

Global internet

Elon Musk, the founder of PayPal, Tesla and SpaceX, is considering launching 700 satellites to provide everyone on the planet with internet access. Google has a similar scheme in the works called Project Loon, which would use high altitude balloons to provide connectivity. Facebook, meanwhile, hopes to do the same using giant drones. Either way, it seems like universal internet access will be coming soon to a village near you.



What’s Not

Insecam

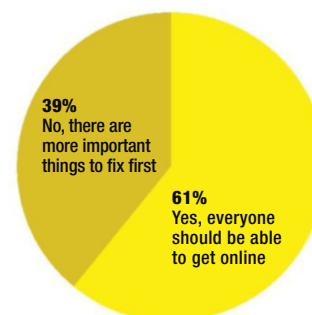
A new website has popped up that wants to bring attention to all the world’s unsecured webcams. Insecam presents live feeds from internet connected cameras, where the users have left the password set as the default key (usually ‘admin’). The site lets you spy on up to 73,000 rooms



that have left their webcams vulnerable, and hopes to prompt naïve users to alter their passwords.

Reader Poll

Is internet access a basic human right?



ILLUSTRATOR: DEM ILLUSTRATION

The Next Big Thing

Bioengineering

Back in 2007, technology journalist Quinn Norton had a magnet implanted under the skin of her finger. When her hand was near an electric field, like that generated by a spinning hard drive, the magnet would respond to the force created and she could sense it. For a while – until the magnet broke up and had to be removed – Quinn had an extra sense, like a shark or an eel. She was an augmented human, and some of us think that was very cool. Others found it a little creepy.

Some forms of technological augmentation have been with us for so long that we don't really notice them. Spectacles, hearing aids, metal knees and even artificial hearts are largely disregarded when it comes to bioengineering. Even some new inventions, like flexible electronic devices that can be printed onto skin and act as health sensors, don't seem particularly strange.

What doesn't seem natural is putting general purpose computers into ourselves and directly interfacing them with our sense organs and nervous systems. In this case, something new is created: a cyborg.

We should prepare ourselves for their arrival because many of us are likely to have some cyborg features in our old age.

A key breakthrough involves direct brain-computer interfaces. Much research in this area is funded by the US Air Force, because flying fast jets is difficult – especially when other people are trying to kill you. So far we have helmets that 'read' the electrical signals from pilots and can manoeuvre jets 'by thought'.

Some devices are classed as neuroprosthetics and are used to replace damaged sense organs. There have been some interesting experiments with blind people who have damaged retinas but healthy optic nerves. By connecting wires from a camera directly to the optic nerve, visual signals can be generated. People seem to be capable of organising these into rudimentary images.

Many deaf people's lives have been transformed by cochlear implants. These tiny computers convert sounds into electrical pulses, which can be interpreted and provide a certain degree of hearing.



But the real change may come when we have direct connections between the brain and a computer system. I don't think we'll ever be able to upload a consciousness into a machine, because the unique organic matrix that hosts it can never be replicated. But we may well build a strong AI and find ways to communicate with it through mechanisms that would be called 'telepathy' if

they weren't grounded in electronic technology.

Until then, a lot can be done to enhance, maintain and secure the physical body, and I am pretty confident we'll end up doing it all. If someone offered me a new eye with zoom, recording capability and enhanced vision, I'd be very tempted to sacrifice my 'lazy' left eye that has never focused properly.

From The Lab

The genetics search engine brought to you by Google

What is it?

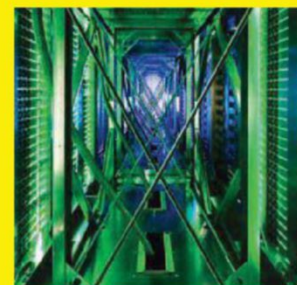
You can already store your pictures and your data in the cloud, so why not your genome, too? The Google Genomics project lets hospitals upload their patients' genetic data onto Google's servers, where it can be compared with thousands (soon to be millions) of other genomes on the database.

Why would I do that?

For a start, each person's genome takes up a lot of storage space: around 100GB. But hospitals will want somewhere to store the data once a genome has been encoded. Compiling genomes on one database will allow researchers to compare and contrast genetics like they have never been able to before.

When will I be able to use it?

There are around 3,500 genomes on the database, but the information is only accessible to researchers and hospitals. As genomic testing becomes cheaper and more widespread, Google aims to open up the service. Amazon, Microsoft and IBM are racing to create competing services.



One of Google's enormous data centres situated in Oklahoma, US

Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

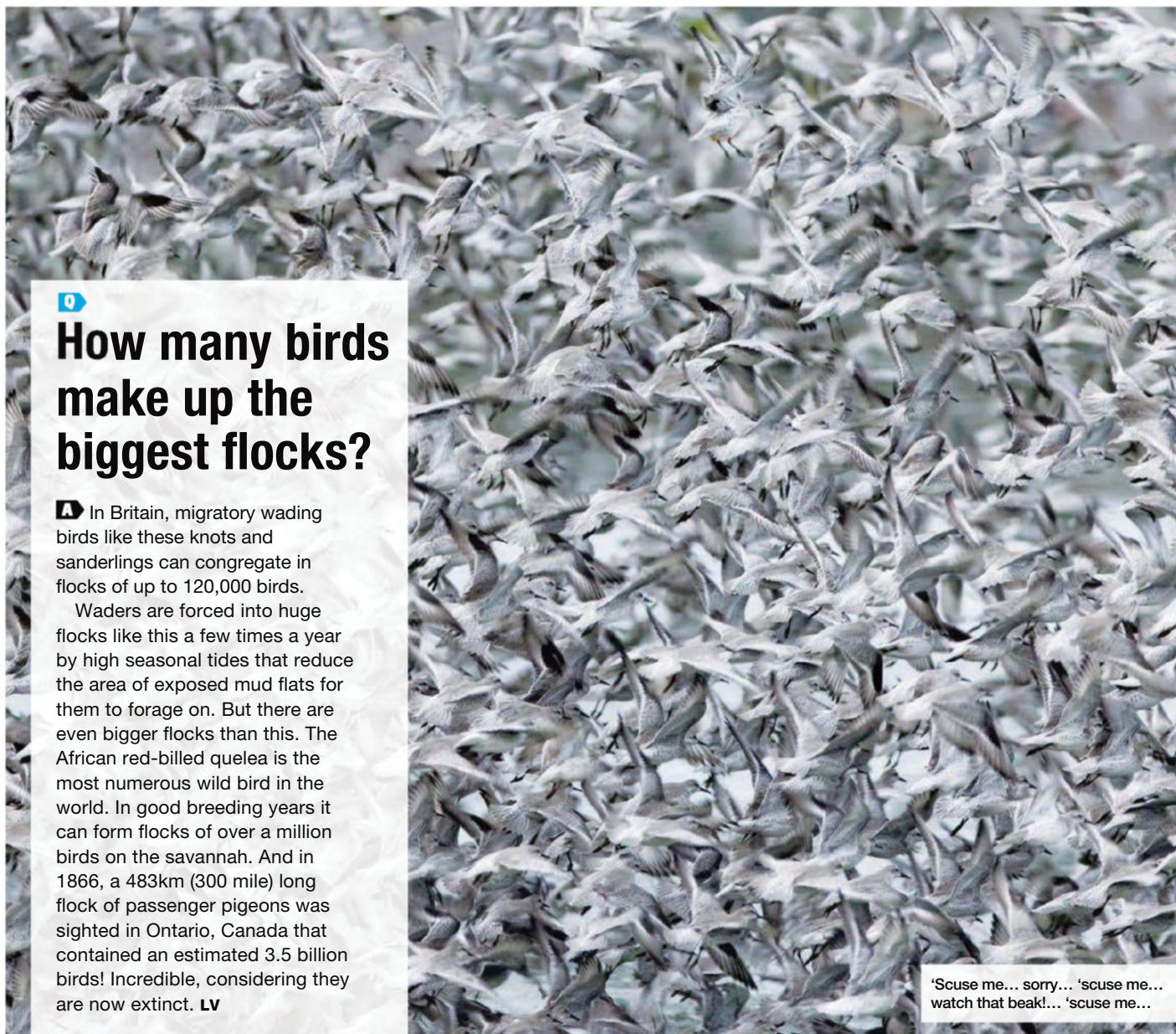
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

editorial-bbcknowledge@regentmedia.sg



Q

How many birds make up the biggest flocks?

A In Britain, migratory wading birds like these knots and sanderlings can congregate in flocks of up to 120,000 birds.

Waders are forced into huge flocks like this a few times a year by high seasonal tides that reduce the area of exposed mud flats for them to forage on. But there are even bigger flocks than this. The African red-billed quelea is the most numerous wild bird in the world. In good breeding years it can form flocks of over a million birds on the savannah. And in 1866, a 483km (300 mile) long flock of passenger pigeons was sighted in Ontario, Canada that contained an estimated 3.5 billion birds! Incredible, considering they are now extinct. **LV**

'Scuse me... sorry... 'scuse me... watch that beak!... 'scuse me...

PHOTO: MARK G SMITH/SOLENT NEWS

In Numbers

221

is the amount of times a British smartphone user checks their device in a day, according to a study commissioned by Tecmark

Are spiders really scared of conkers?

A Putting conkers around the house to deter spiders is an old wives' tale and there's no evidence to suggest it really works. Spiders don't eat conkers or lay eggs in them, so there is no reason why horse chestnut trees would bother to produce spider-repelling chemicals. There is no hard research on the subject, but pupils of Roselyon Primary School in Cornwall won a prize from the Royal Society of Chemistry in 2010 for their informal study (youtu.be/pdZRMm2VSR4) showing that spiders were unphased by conkers.

Spiders are most common indoors in the autumn months. At this time of year, male house spiders leave their webs and start wandering in search of females. If you Hoover up all the spiders in your house, it will probably take a couple of weeks for the spiders to recolonise – regardless of whether or not you scatter conkers around the place. **LV**



With one of these suits, you could carry 90kg – perfect for all your sales shopping

Will cybernetic human enhancement happen?

A The US military is trialling Lockheed Martin's HULC (Human Universal Load Carrier). This exoskeleton enhances soldiers' abilities through hydraulic actuators. These are controlled by a central processor that takes signals from sensors around the suit. The wearer can run and jump while bearing loads of up to 90kg.

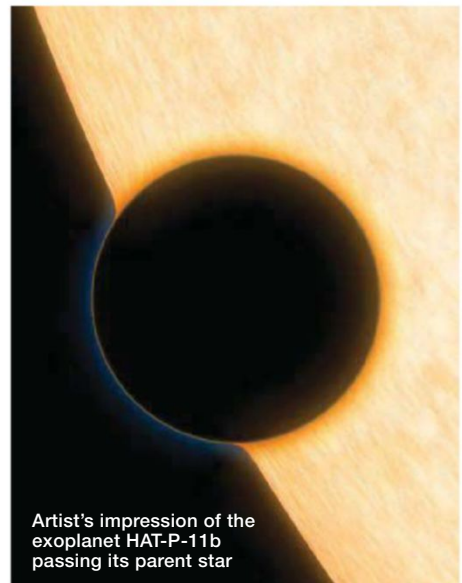
Not to be outdone, the French military has its Hercule 'exosquelette'. It is slightly heavier than HULC but more energy efficient,

meaning that less of its weight is taken up with batteries.

Some diseases affect the light-detecting rod and cone cells in the retina. But in 2013, German researchers unveiled an Alpha IMS implant; when inserted into a patient's retina, the Alpha IMS detects light entering the eye and converts it into electrical signals which are fed to the brain. In future, similar technology promises to work in infrared to ultimately surpass our natural vision. **GM**

How is H₂O found on exoplanets?

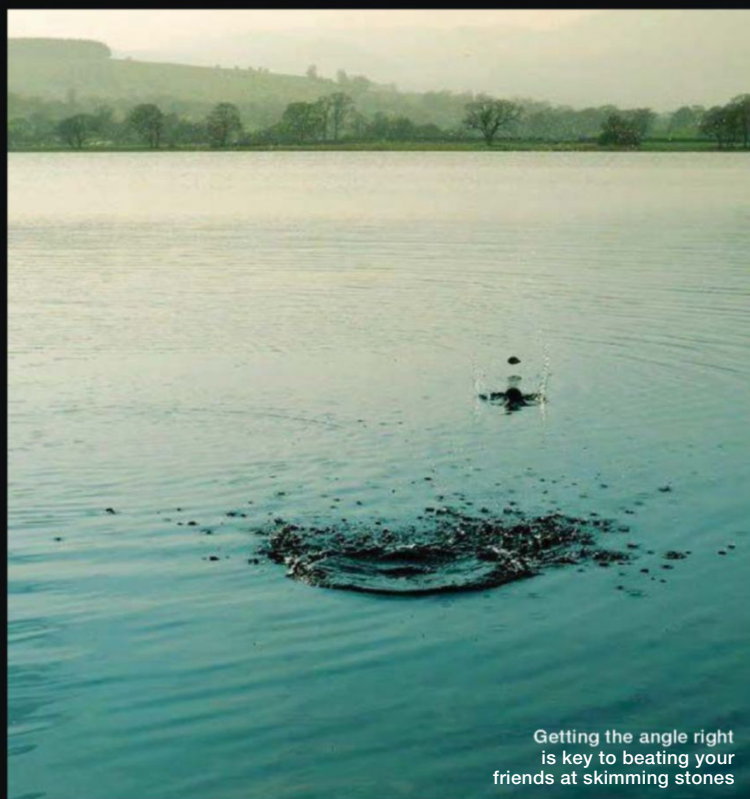
A Exoplanets are planets outside our Solar System and it's possible to detect water in their atmospheres. The planet is observed as it crosses the face of its parent star. The star's light filters through the edge of the planet's atmosphere and molecules such as water can absorb some of the starlight. This results in distinct absorption bands in spectra of light – these are only present during the planet's transit. Comparison of spectra can reveal the presence of substances such as water, methane, sodium and nitrogen. It's tricky to do, given the small amount of absorption observed, so astronomers have to be certain the absorption isn't happening in the star's own atmosphere. Water has been detected on at least five large exoplanets. Recently, traces were detected on HAT-P-11b, a Neptune-sized planet that's the smallest known to have water to date. **AG**



Artist's impression of the exoplanet HAT-P-11b passing its parent star



"Argh! It's a conker!" said no spider ever



Getting the angle right is key to beating your friends at skimming stones

How do stones skim?

A For a pastime dating back at least to the ancient Greeks, it's odd that the science behind skimming stones has only recently attracted scientific interest. After all, there's plenty to ponder. What stops the stones from sinking like, well, stones on impact? And what's the secret to maximising the number of skips?

Some answers emerged in 2004, when a team led by Christophe Clanet of the French National Centre for Scientific Research (CNRS), Marseille, published theoretical and experimental results in the journal *Nature*.

As every skimmer knows, shape, speed and spin-rate are

all important. The team showed, however, that it's the angle to the water that is most important in getting plenty of skips. If the stone hits the water too steeply, it plunges in and sinks. Too shallow an angle causes it to slow down, lose energy and fail to bounce back up off the water. According to the team, the ideal angle is around 20° to the water.

Shape, speed and spin-rate are still important, however. A flat stone is best, with the number of bounces increasing with speed of throw. A high spin-rate also gives the stone gyroscopic stability, helping it to maintain the right angle relative to the water on each bounce. **RM**

Q

Why are rainbows circular when viewed from an aeroplane?

A Rainbows are formed when light emerges from water droplets that are in just the right place for the rays to enter our eyes. Such droplets always lie on a circle facing the Sun. Unless we're airborne we can only see a 'bow', as the ground blocks out the rest. **RM**



But where will you find the pot of gold?

Q

Why do jokes get less funny after repetition?

A Because suspense, surprise, violated expectations and the release of tension can all make us laugh and those tricks rarely work twice. If you're asked, "What gets wetter the more it dries?" and you didn't get that one as a kid, you'll struggle to think of an answer until someone says: "Ha, ha, it's a towel". That joke is forever less funny because you no longer bother trying to work it out. Yet some jokes do remain amusing; there is even the well-known comedians' trick of the 'funny, then not funny, then funny again' joke.

These require skill and plenty of time to tell, but they do lure people into laughing again. **SB**



In our opinion, whoopee cushions never get old

TOP TEN

BRAINS OF LAND ANIMALS

(BY WEIGHT)



1. Elephant

Brain weight: 4,780g
Average brain/body mass ratio: 1/560



2. Adult human

Brain weight: 1,300g
Average brain/body mass ratio: 1/40



3. Camel

Brain weight: 762g
Average brain/body mass ratio: 1/800



4. Giraffe

Brain weight: 680g
Average brain/body mass ratio: 1/1485



5. Hippopotamus

Brain weight: 582g
Average brain/body mass ratio: 1/2789



6. Horse

Brain weight: 532g
Average brain/body mass ratio: 1/600



7. Gorilla

Brain weight: 500g
Average brain/body mass ratio: 1/240



8. Polar bear

Brain weight: 500g
Average brain/body mass ratio: 1/1000



9. Cow

Brain weight: 450g
Average brain/body mass ratio: 1/700



10. Chimpanzee

Brain weight: 420g
Average brain/body mass ratio: 1/113

PHOTO: NASA/JPL X2, GETTY, ALAMY, SCIENCE PHOTO LIBRARY



Are black holes always found at the centre of galaxies?

Black holes are tricky to detect, so astronomers have to track their effects on their environment

A Although it seems very likely that most spiral galaxies (and possibly all types of galaxies) contain a black hole, these are not the only places that these gravitational beasts reside. By their very nature black holes are not directly observable and astronomers rely on their effects on their environment to detect them. The disc of material orbiting a black hole can become extremely hot and emit huge quantities of radiation (mainly X-rays), which may

be detected by telescopes. Many of the Universe's more energetic phenomena have therefore been attributed to the accretion of matter by black holes. These include discs that eject powerful beams of X-rays.

Astronomers have also discovered isolated, stellar-mass black holes adrift among the stars in our Milky Way. These have been found indirectly by measuring how their extreme gravity bends the light of a more distant star behind them. **AG**



How many elements make up Earth?

A There are 118 elements in the periodic table and 98 of them occur naturally on Earth. But just eight (iron, oxygen, silicon, magnesium, sulphur, nickel, calcium and aluminium) make up almost 99 per cent of Earth's mass. Carbon, present in every living thing, accounts for just 0.07 per cent of the Earth's mass. When the Earth formed, denser elements sank to the core. The crust has a higher percentage of lighter elements, like oxygen and aluminium, and much less iron than the planet as a whole. Elements 83 and above are radioactive and are gradually disappearing, due to radioactive decay. Above number 98, this decay is so fast that the elements are only found in the lab. The last element, ununoctium, is so unstable that only three or four atoms have ever been detected. **LV**



Just eight elements make up nearly 99 per cent of Earth

Why do we hold our breath in suspense situations?

A One reason is that anger, fear and strong emotions cause our muscles to tense, including the thoracic diaphragm and the abdominal and chest muscles that are used in breathing. Tension in the neck and shoulders also restricts our lungs. A more specific reason is that keeping absolutely still may be the safest strategy when we are threatened or uncertain. Holding our breath means we can hear more acutely and possibly even see more clearly because our head doesn't move. And keeping very still means we are less likely to be detected by a predator or enemy. We also tend to breathe in deeply before holding our breath. Through the action of the vagus nerve, this increases the heart rate, therefore pumping more oxygen around the body. Holding our

Holding your breath may prevent a tiger from detecting you – but we don't recommend it



breath in such situations is quite natural and harmless, but frequent breath-holding can be a problem. Good, regular, full breathing is important for health. **SB**

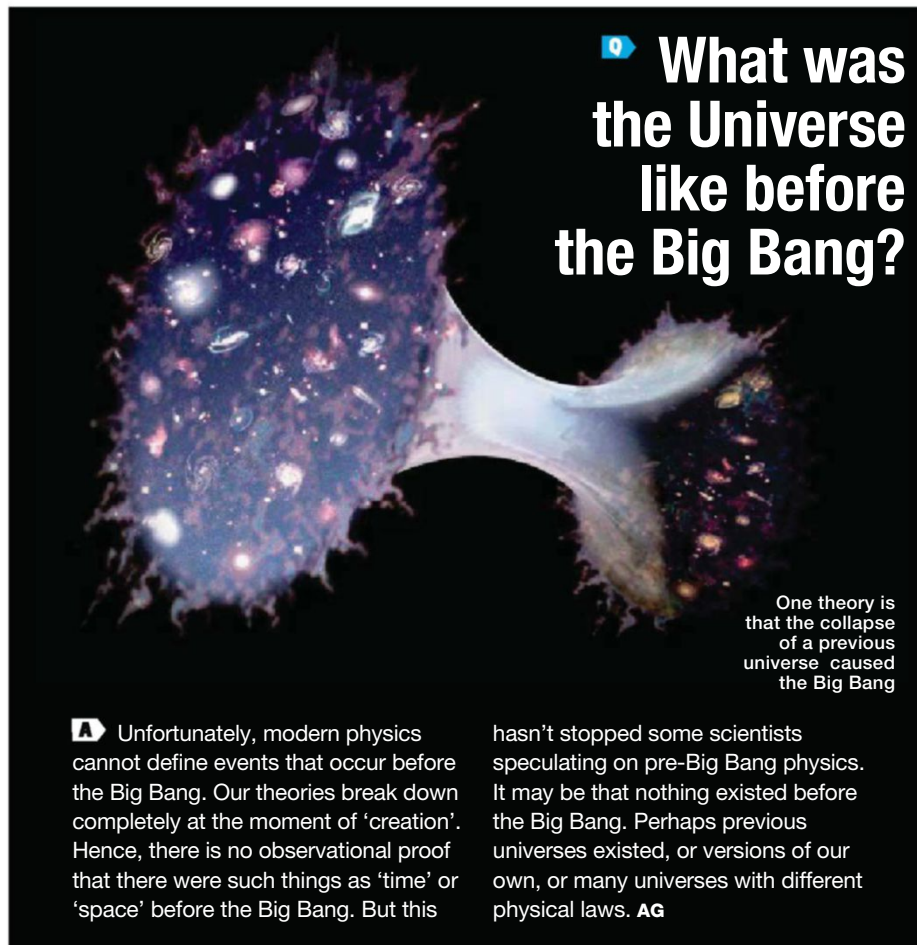
Will long-range weather forecasts become increasingly accurate?

A The Met Office says that four-day forecasts are now as good as the one-day forecasts of the mid-1980s. The truly long-range – more than a month or so ahead – will never be as reliable. The atmosphere is chaotic, with tiny observational errors growing over timescales of 10 days or so to wreck any forecast. **RM**

Want accurate month-long forecasts? You'll be waiting a while



What was the Universe like before the Big Bang?



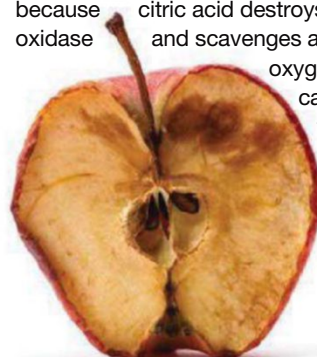
One theory is that the collapse of a previous universe caused the Big Bang

A Unfortunately, modern physics cannot define events that occur before the Big Bang. Our theories break down completely at the moment of 'creation'. Hence, there is no observational proof that there were such things as 'time' or 'space' before the Big Bang. But this

hasn't stopped some scientists speculating on pre-Big Bang physics. It may be that nothing existed before the Big Bang. Perhaps previous universes existed, or versions of our own, or many universes with different physical laws. **AG**

Why do apples turn brown after being cut?

A Apples contain chemicals called phenols that act as protection against fungi and bacteria. When the fruit is damaged, these phenols are exposed to the air and an enzyme called polyphenol oxidase catalyses a chemical reaction that combines phenols and oxygen to form the brown pigment melanin. This makes an insoluble layer over the cut surface that slows fungal infection. Applying lemon juice to the cut surface prevents browning because citric acid destroys polyphenol oxidase and scavenges any surface oxygen before it can react with the phenols. **LV**



Someone didn't know the lemon juice trick...



Prime numbers are increasingly important for security

Why are prime numbers so important?

A The clue is in the name. Starting with one and the primes, it is possible to create all the other numbers. Ancient Greek mathematician Euclid proved there is an infinite supply of primes, and that every number greater than one is either a prime or the result of multiplying a unique combination of primes together. Given their role as the building blocks of numbers, primes have fascinated mathematicians ever since. This has led to some practical applications of prime numbers – the most famous of which is so-called public key encryption, which is widely used to keep electronic data secure. Public key encryption relies on the fact that while it's easy to multiply two huge primes together, there's no known way to rapidly do the reverse: breaking apart a huge number into its prime factors. That's not to say that such a method does not exist, but finding the existence of a quick factoring method is the focus of intense research. **RM**

In Numbers

30m

is the diameter of the mirror of the Thirty Meter Telescope, which will be one of the world's biggest. Construction has begun in Hawaii

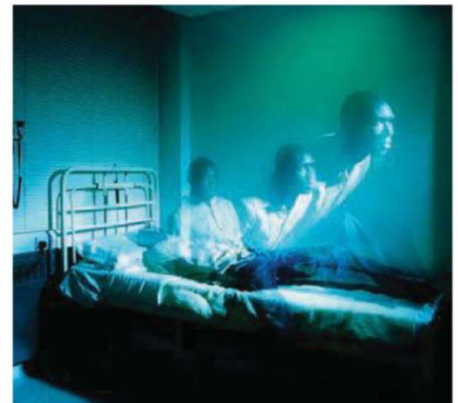
Q

Can science explain near-death experiences?

A Yes, and increasingly well. About 10 per cent of those resuscitated when close to death report some aspects of a near-death experience (NDE). The tunnel and bright light occur when a flood of random activation flows through the visual system. The out-of-body experience is caused by disruption of the brain's temporo-parietal junction, which uses sensory information to construct our normal body image. When stimulated with electrodes or deprived of data, the junction fails and out-of-body experiences (OBEs) can result. Most report a feeling of peace and acceptance. This is caused by the release of morphine-like endorphins.

There are claims of vision or hearing during NDEs that, if properly substantiated, would show that there is

more to NDEs than neuroscience can explain. But I have investigated many such claims and never found the evidence compelling – so far. **SB**



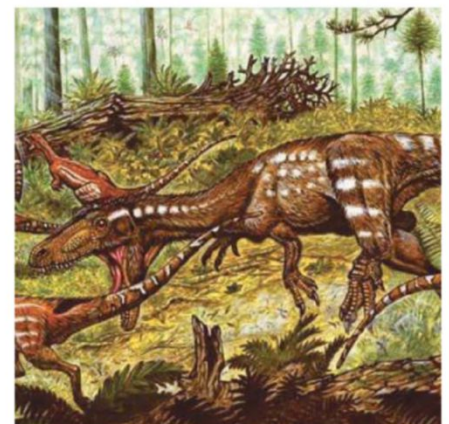
Q

Which countries shop online the most?

A At number one is the UK, with 60 per cent of adults shopping online, spending just over £68bn. This is according to the most up-to-date figures from the Organisation for Economic Co-operation and Development (OECD), published in 2012. The UK is double the OECD average and is followed by Denmark, where 53 per cent of people shop online. Germany and France are at 48 and 42 per cent respectively. **GM**



The UK leads the OECD world in online shopping



Q

What dinosaur was found most recently?

A About 30 new dinosaur species are discovered every year, so that's one every week or two. One of the most recent was *Tachiraptor admirabilis*, which was a 2m-tall raptor that lived 201 million years ago in what is now Venezuela. There are an estimated 1,800 different dinosaur genera, of which around 30 per cent have been discovered so far. **LV**



HOW IT WORKS

BLOOSTAR ORBITAL ROCKOON

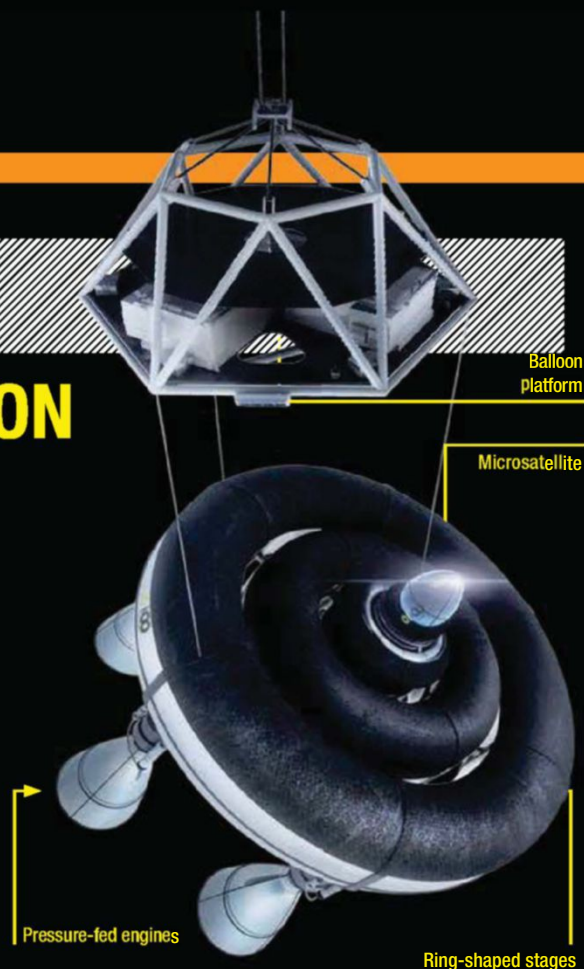
The problem with rockets is the fuel they carry. Rocket designers need to take the weight of the fuel itself into account when deciding how much is required to launch people or satellites into orbit. But if you could take a rocket high into atmosphere on a balloon, you could save a lot of weight. That's the idea behind the 'rockoon', and Spanish company zero2infinity has just announced one called bloostar. It won't replace today's heavy lift rockets. But it is big enough to launch microsatellites – payloads up to 75kg – into orbit.

The balloon is filled with helium gas and is launched from an ocean-going vessel to reduce wind issues.

The launch takes place in multiple stages to take the satellite into orbit. Once each stage has fired it drops out of the sky, to be recovered later. This clean launch process uses less fuel, as ignition does not take place until the vehicle is above 99 per cent of the planet's atmosphere.

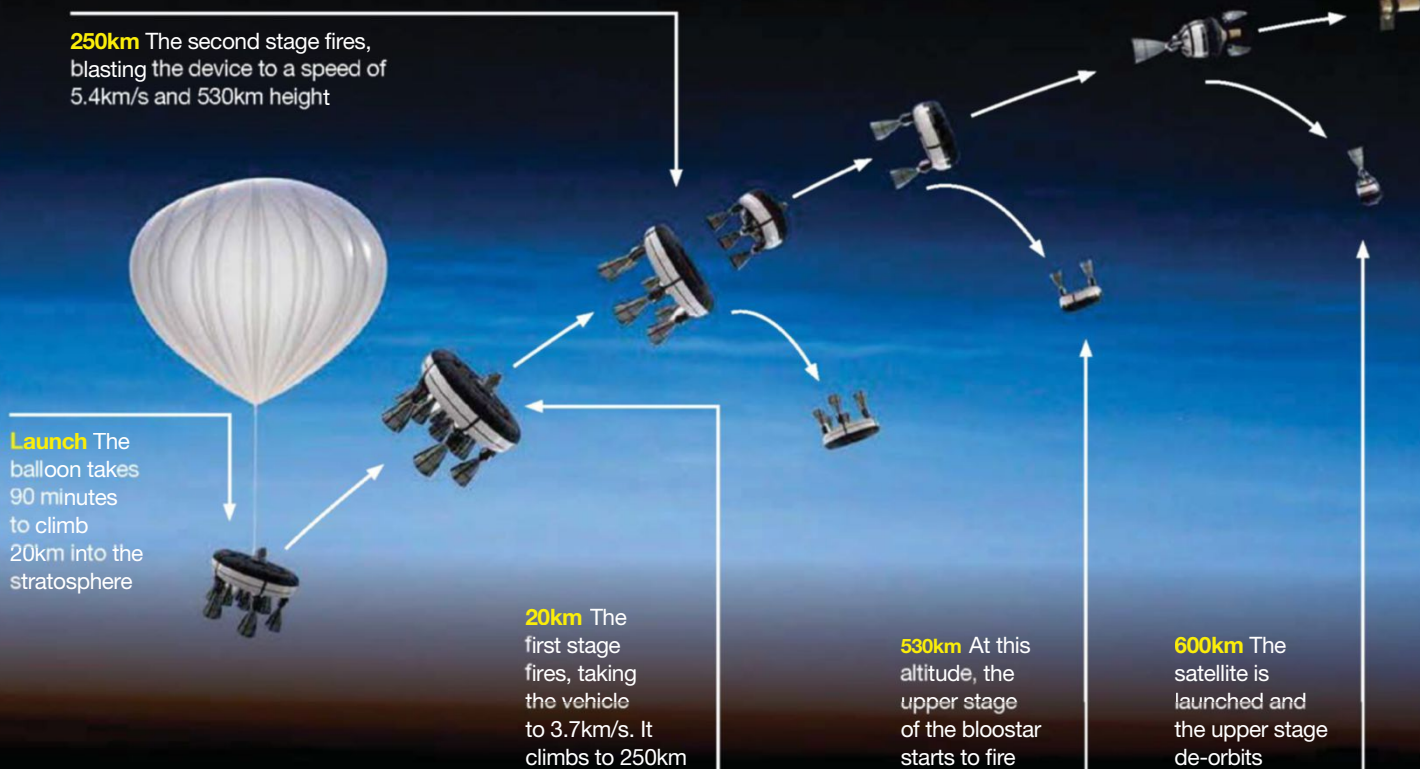
Its pressure-fed liquid-fuelled engines are also cost-effective. The rockets are ignited in near-vacuum conditions, translating to less drag and more effective use of nozzles.

The system has already been tested, with successful results. The bloostar will be operating by 2017 and zero2infinity says it's already had interest from microsatellite companies.



THE LAUNCH CYCLE

Orbit The bloostar can launch a 75kg payload into orbit, which can be a single satellite or multiple payloads





Q

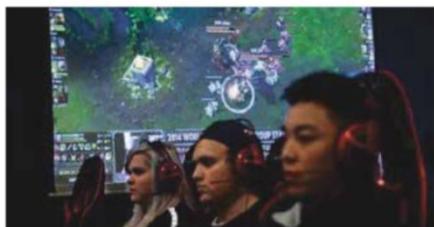
How overweight do you have to be to break your ankles?

A It's not simply a question of weight. Behdad Salimi won weightlifting gold at the London Olympics. His 168kg and BMI of 43 would normally be considered obese, yet he was able to lift 247kg without injuring his ankles. In general though, ankle fractures do get more likely – and more severe – as you get

heavier, even though obese people are less active. Korean dictator Kim Jong-un is believed to have suffered broken ankles recently, but this may have had as much to do with the Cuban heels he wears to boost his height as the weight he has gained since coming to power. **LV**

Q

What's the most played online game?



Robert Morris University offers scholarships for LOL players

A The multiplayer online battle arena game *League Of Legends* is number one. Its developers say it has 27 million players daily. Gamers take on the role of 'champions' who progress by killing those of their opponents.

Figures from the influential gaming social network Raptr from September 2014 report that the game accounted for 21.6 per cent of playing time on its platform. *World Of Warcraft* was in second place with 7.6 per cent. GM

Q

Are organic vegetables healthier than GM vegetables?

A A study at Newcastle University in 2014 found that organic fruit and vegetables had higher levels of antioxidants than non-organic varieties. This isn't too surprising – since plants make antioxidants to fight off insects, organic farmers normally grow varieties that naturally produce larger amounts of these substances.

Organic fruit and vegetables also have lower levels of pesticides than normal crops, but so do GM vegetables because they have been genetically engineered to be pest-resistant. This cuts down on the need to spray the crops.

Unlike vitamins, however, plant antioxidants are not essential nutrients for

humans – and some antioxidants are even harmful. So organic vegetables aren't necessarily better for you than genetically modified or regular crops. The proportion of fruit and vegetables in your daily diet has a much bigger effect on your health than the way in which they are grown. **LV**



Even if it's not organic, sweetcorn is still good for you

Q

What causes stuttering?

A No one knows for sure, although stuttering sometimes runs in families and a few specific genetic mutations have been discovered. Stuttering (or stammering) is found across many cultures, affecting four times as many men as women. It is estimated that 70 million people worldwide are affected. Stuttering usually begins in early childhood with about 5 per cent of both boys and girls affected, but girls are more likely to grow out of it as they get older.

Differences in the brains of people who stutter have been found, including poorer coordination between speech and planning regions in the left hemisphere. It is not known whether these variations cause the stuttering, or whether stuttering itself causes changes in the brain. Although acute stress can bring on episodes of stuttering creating a positive feedback loop, stress is not thought to be the underlying cause. **SB**

George VI, as portrayed by Colin Firth, is one of history's most famous stutterers

Q

What is 'dying of old age'?

A If you manage to avoid a fatal car crash, infectious disease, heart failure, cancer, suicide and murder, you should make it into your eighties. At this point, all your organs will have lost some of their effectiveness. Your kidneys won't quite manage to filter all the toxins from your blood; your heart won't pump that blood quite hard enough to fully oxygenate your extremities; your digestive system won't have the same appetite or capacity that it used to and so on. This makes you progressively more vulnerable. Doctors don't use 'old age' or 'natural causes' on death certificates much any more; they always try to list both the immediate cause of death and the underlying cause as well. So 'cardiac arrest' might be the immediate cause and 'heart disease' the underlying cause. But elderly people often have several chronic conditions at the

same time and it's nearly impossible to tell exactly which organ failed first without a post-mortem, which is rarely performed on elderly patients. Death is inevitable and gets more likely as you get older, so you can think of old age as the ultimate underlying cause of death. But 'old age' itself is never an immediate cause of death. It's just an informal way of saying that a person has died without any suspicious circumstances or previously known acute medical condition. **LV**

YOUR QUESTIONS ANSWERED

E Email to editorial-bbcknowledge@regentmedia.sg. We're sorry, but we cannot reply to questions individually.

B Hardback **P** Paperback

Life On The Edge

The Coming Of Age Of Quantum Biology

Jim Al-Khalili and Johnjoe McFadden

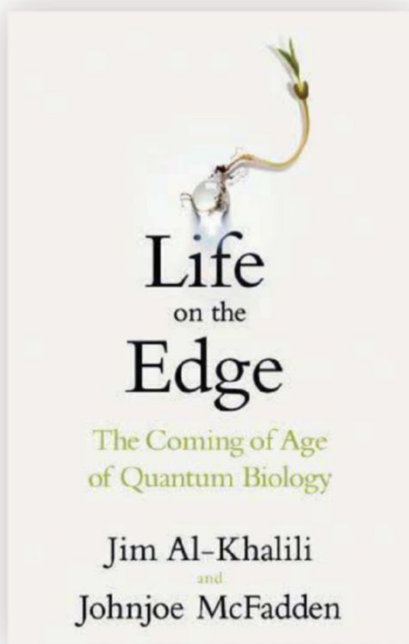
Bantam Press **B**

Quantum physics is wonderfully counter-intuitive and describes how tiny things such as atoms work. For larger things, involving many atoms, quantum weirdness gets washed out, leaving behind the world with which we are familiar: a world in which objects are alive or dead, but not both at the same time. In the past, biologists have not had much reason to turn to quantum physics. But, as this book explains, things are changing.

Al-Khalili and McFadden are impassioned, and they make no secret of their belief that quantum physics has played a crucial role in the emergence of life and how it manifests itself. They suggest that the natural world has learnt to harness the noisy molecular environment that's usually responsible for killing off quantum behaviour in large systems – and that we may one day learn to do likewise.

Life On The Edge takes us on a tour of ideas spanning quantum physics, biology and biochemistry. We learn that enzymes exploit 'quantum tunnelling' to shift electrons and protons around biomolecules. Quantum tunnelling is akin to the apparently impossible act of walking through walls, and it's well known for its role in the radioactive decay of single atoms. What's both surprising and intriguing is that tunnelling can also be discovered taking place inside large biomolecules.

“Life On The Edge takes us on a tour of ideas spanning quantum physics, biology and biochemistry”



Next we meet photosynthesis, and the uncanny way by which plants harvest sunlight. It turns out that the energy a plant receives is sent to where it's needed by a process that exploits the mind-boggling quantum idea that a particle will travel from A to B via all possible routes at the same time. After that, we go on a journey that involves the sense of smell, how butterflies and birds migrate, the copying mechanism of genes, the workings of the brain and the origins of life. It's an exhilarating list.

In places, the prose is terrific. I enjoyed reading about the annual voyage of the monarch butterfly from southeast Canada to central Mexico in particular. But the book isn't without its flaws. It's arguably a little too ambitious in scope, and in places I was entirely lost in the biochemistry. It would also have been better without the hackneyed use of superlatives and catchy one-liners: at one point I counted four instances of 'remarkable' and one 'amazing' in a handful of lines.

But these are minor points. *Life On The Edge* is nevertheless an important book, and one I found hard to put down.

JEFF FORSHAW is a professor of theoretical physics at the University of Manchester

MEET THE AUTHOR



Jim Al-Khalili

Where in the natural world have scientists found quantum effects?

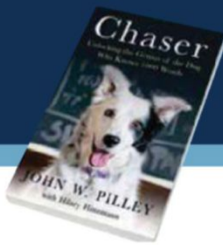
The most beautiful example is the way that robins migrate by sensing the Earth's magnetic field. The Earth's magnetic field is 100 times weaker than a fridge magnet, so how can it affect chemical reactions, as it must do if it's going to influence an animal? The leading theory is that inside the bird's eye there are two electrons that are quantum entangled – two particles that are far apart but able to communicate instantaneously. This makes the electrons very sensitive to the bird's orientation within the magnetic field, allowing it essentially to 'see' the Earth's magnetic field – an incredible idea.

How important a role do you think quantum mechanics plays in biology?

I think we're going to find it plays a much more fundamental role than we imagined. Evolution will make use of any tricks available to make the process more efficient, so if the quantum world gives life an advantage, then it will use quantum mechanics. I think we'll discover many more examples in the years to come.

Could the findings of quantum biology have any technological applications?

It's far too soon to tell, but we can speculate. If plants have utilised the quantum world to make photosynthesis more efficient, then can we use that idea when building artificial solar cells? That's one of the issues blocking the advance of solar energy – poor efficiency. Also, if we can sense things like a weak magnetic field using quantum entanglement, then who knows what technological advances it might allow us to develop in the coming decades?



Chaser

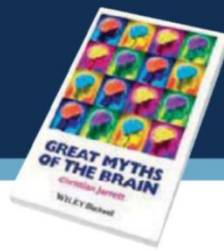
John W Pilley with Hilary Hinzmann
Oneworld **P**

All animals are as intelligent as they need to be in their own environments. So when it comes to attempting to teach aspects of our language to another species, there's perhaps no better subject than a border collie – specifically bred to be hyper-attentive to our every command. And Chaser, a sprightly and enthusiastic 10-year-old dog, doesn't disappoint.

In this charming tale of man and dog, John Pilley dedicates his retirement years to teaching his loyal companion over a thousand words, and even goes on to teach her combinations of actions and objects, like 'paw the ball' or 'fetch the Frisbee', instructions that Chaser seems to rejoice in executing. Whether Chaser can indeed learn words in a similar way to an infant remains a hotly debated topic among animal behaviourists, but what's in no doubt is Pilley's passion and determination in revealing more about your dog's cognitive capabilities.

What Pilley lacks in storytelling prose, he makes up for with fascinating facts about canine intelligence and practical tips on how to enrich your dog's quality of life. Dog owners everywhere will never look at their pets in the same way again. I predict a bumper year for dog toy sales.

LIZ BONNIN is a broadcaster who recently presented *Cat Watch 2014* on BBC Two



Great Myths Of The Brain

Christian Jarrett
Wiley Blackwell **P**

Christian Jarrett's *Great Myths Of The Brain* is the sort of book that every amateur brain enthusiast should have on his or her shelf. The book is an effort to assemble all the common and not-so-common myths about the brain, past and present, and explain why they're all wrong using genuine neuroscience.

For such a mammoth undertaking, Jarrett succeeds admirably, presenting a clear and well-structured debunking of erroneous brain beliefs, which are becoming increasingly widespread. It's not without its flaws, of course. Jarrett's tone is that of an earnest but friendly lecturer, which fits the material but may prove off-putting to more scientifically experienced readers. What's more, several of the 'myths' tackled by Jarrett seem more like understandable misconceptions, or are things most people will never have heard of. It would be a cruel irony for readers to learn new myths about the brain from a book that's intended to combat them!

But these minor issues aside, Jarrett has done sterling work and *Great Myths Of The Brain* would make a good go-to reference for anyone encountering dubious claims about the brain.

DEAN BURNETT is a neuroscientist and comedian. He lectures at Cardiff University



Galaxy: Mapping The Cosmos

James Geach
Reaktion Books **B**

The night sky is a landscape that has captured the imaginations of millions. Today, we're learning more about the Universe than ever, and James Geach is at the forefront of the quest to find out more.

In *Galaxy: Mapping The Cosmos*, we are shown our current understanding of the 'island universes' that surround us, but are too distant to see without powerful telescopes. As we move through the cosmos, Geach explains complicated ideas in modern astronomy so that they are understandable by anyone with a basic grasp of physics.

The book contains dozens of stunning images of galaxies and nebulae, showing the beauty that lurks among the gas and dust of these complex systems. But the decision to contain only photographs means that some scientific descriptions become overly complex, as there are no diagrams to help explain the concepts.

The book also gives us an insight into how modern astronomers go about their business, such as by creating simulations that attempt to replicate the entire Universe. The book is an excellent guide to a world many of us never get to see, both on and off this planet.

ELIZABETH PEARSON is staff writer at BBC Sky at Night Magazine



Why Aren't We Dead Yet?

The History And Power Of Great Ideas
Idan Ben-Barak
Scribe **P**

I liked the title of this book and am interested in the topic – "the survivor's guide to the immune system" – so I had high hopes when I picked it up. Unfortunately, the title was in many ways the best thing about it. Yes, it does take you on a fairly comprehensive journey through the "fantastic, perplexing, and troublesome wonder known as the immune system" but it lacks the vital spark that really good science writing has – a way of hooking you in and engaging you in an unfolding story.

I don't think it helps that Ben-Barak reverses the usual rules of popular science writing. Many writers tease their audience with some

stories from the past that make the reader want to understand. Then they move in for the kill, explaining why theories evolved and how we got to where we are now. This book, however, starts with the technical descriptions and brings in the history later. The author is to be applauded for trying something different, but sadly he hasn't really pulled it off.

There is no doubt a great book to be written on this subject, but this is not it.

MICHAEL MOSLEY is a medical journalist and BBC presenter who appears on *The One Show*

Time Out

In the know

SET BY DAVID J BODYCOMBE

1 Prof Stephen Hawking has warned that what could bring on the end of humankind?

- a) Artificial intelligence
- b) Drones
- c) Sea level rise

2 The world's most complete Stegosaurus skeleton has gone on display in London's Natural History Museum. Roughly how old is it?

- a) 50 million years old
- b) 100 million years old
- c) 150 million years old



Roughly how old is this spiny specimen?

3 Complete the recent headline: 'Brain changes seen in young _____',

- a) Black belts
- b) Heavyweight boxers
- c) American footballers

4 Scientists in the UK have developed a chemical that can be added to food to do what?

- a) Make you feel full
- b) Make anything taste like chocolate
- c) Make it smell better

5 Which video recently broke YouTube's view counter, amassing more views than the

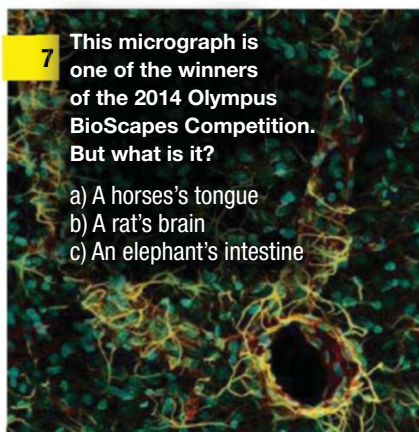
website's 32-bit counter could cope with?

- a) PSY – 'Gangnam Style'
- b) Justin Bieber – 'Baby' ft Ludacris
- c) Miley Cyrus – 'Wrecking Ball'

6 According to a new study, people who are left-handed...

- a) Earn less money than right-handers
- b) Have a higher IQ than right-handers
- c) Tend to be more musically gifted than right-handers

7 This micrograph is one of the winners of the 2014 Olympus BioScapes Competition. But what is it?



- a) A horse's tongue
- b) A rat's brain
- c) An elephant's intestine

8 To help them explain the science of polymers, two physicists at the University of Warwick have invented a new kind of...

- a) Bread
- b) Pasta
- c) Beer

9 UFO enthusiasts claim to have spotted a rock on the surface of Mars resembling what?

- a) Barack Obama's head
- b) Kim Kardashian's derrière
- c) Mickey Mouse's ears

10 Which of these English locations has *not* been chosen as a host for driverless car tests next year?

- a) Greenwich
- b) Milton Keynes
- c) Birmingham

11 Researchers working with the Curiosity rover recently reported detecting 'belches' of which gas on Mars?

- a) Nitrogen
- b) Methane
- c) Oxygen

12 Scientists at Bielefeld University have created Hector, a robot based on which creature?

- a) Hummingbird
- b) Stick insect
- c) Hedgehog

13 Which of these was selected as 2014's Breakthrough Of The Year by the journal *Science*?

- a) The development of 'neuromorphic' computer chips that mimic the brain
- b) The discovery of the world's oldest cave art in Indonesia
- c) The European Space Agency's comet-landing mission, Rosetta

14 Complete the recent headline: 'NASA emails _____ to space station'

- a) Spanner
- b) Hammer
- c) Screwdriver

15 Scientists exploring the Mariana Trench have discovered the deepest known fish. How far beneath the waves was the snailfish discovered?

- a) 4,145m
- b) 6,145m
- c) 8,145m

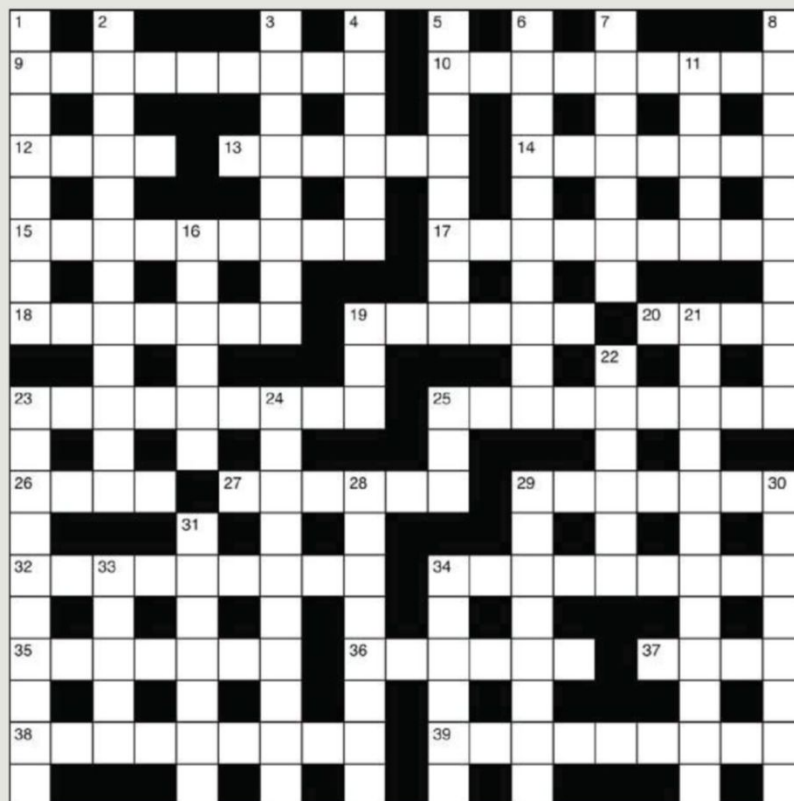
Crossword No.174

ACROSS

- 9 Suffocating mixture of gag, attorney and politician (9)
- 10 Vegetarian chap takes mineral after four (9)
- 12 Flutes conceal another instrument (4)
- 13 Steer new course, only using two speakers (6)
- 14 Circus act to catch relaxation, say (7)
- 15 Rule again about pain (9)
- 17 Yet another speed is inferior (5-4)
- 18 Having money, yet getting thinner (7)
- 19 Discover depth (6)
- 20 Was obliged to get hitched before getting old (4)
- 23 Capital Frenchman finds a dough is wrong (9)
- 25 Religious belief has to notice tyranny (9)
- 26 Carry drink to get energy (4)
- 27 Poison seldom spotted by copper first (6)
- 29 Fellow on about liberty endlessly is a nut (7)
- 32 Solved crime, bit using old and new type of data (9)
- 34 Single professor takes on strange mammal (9)
- 35 Look round first for spear (7)
- 36 One bear wandering around one peninsula (6)
- 37 Lack a young woman (4)
- 38 Stands awkwardly on single rock (9)
- 39 About student solving a clue, having time to compute (9)

DOWN

- 1 Muscle needed to climb sun, improbably (8)
- 2 Model village left with natural illumination (4,8)
- 3 King has a race around gate to strait (8)
- 4 Betting craft reaches a former Greek city (6)
- 5 Cooked the roast with variable resistance (8)
- 6 Life-sustaining expert wears one suit (10)
- 7 Primarily seasonal composer (7)
- 8 Vote to mention conclusion with hesitation (10)
- 11 Last character only played game (5)
- 16 Time and motion schedule (6)
- 19 Reportedly rushed to bring complaint (3)
- 21 Flier broke warhead limit (5,7)
- 22 Mythical creature rewrites blog at home (6)
- 23 Mobile mast affected chemical processes (10)
- 24 Old-fashioned origin of 100 would be 10 (6,4)
- 25 Dutch and Old English word for an animal (3)
- 28 Records herb the other side of a river (8)
- 29 Wrong of students to force lice into cavity (8)
- 30 Snug tent made out of metal (8)
- 31 Medic to study its fluctuating temperature (7)
- 33 Alternatively charge to see some stars (5)
- 34 Smell of small fish (6)



SOLUTION TO CROSSWORD 171



QUIZ ANSWERS

15c
12b, 13c, 14a,
9a, 10c, 11b,
5a, 6a, 7b, 8b,
1a, 2c, 3c, 4a,

HOW DID YOU SCORE?

0-5 Shallow end
6-10 Deep end
11-15 Mariana trench

The Last Word

Researchers should stop being so secretive about their studies

University libraries can be intimidating places. As a student, I used to feel overawed by the sheer amount of learning crammed onto the shelves, including books, journals and PhD theses. What hope was there of contributing anything new to such a vast store of knowledge?

These days I increasingly find myself asking another question: given all this knowledge, why don't we have solutions for everyday challenges? Take one that rears its head at this time of year – how best to break a bad habit. By tradition, we make a New Year's resolution to, say, eat less junk. Generally, we keep it up for a few weeks (or, in my case, hours), then crack and give up.

We've all been there and we'd all like to do better, but we don't know how. Those most likely to have the answers are the research psychologists whose output fills those journals on university library shelves. But chances are you'll find their work as comprehensible as a tax return from the Ming Dynasty.

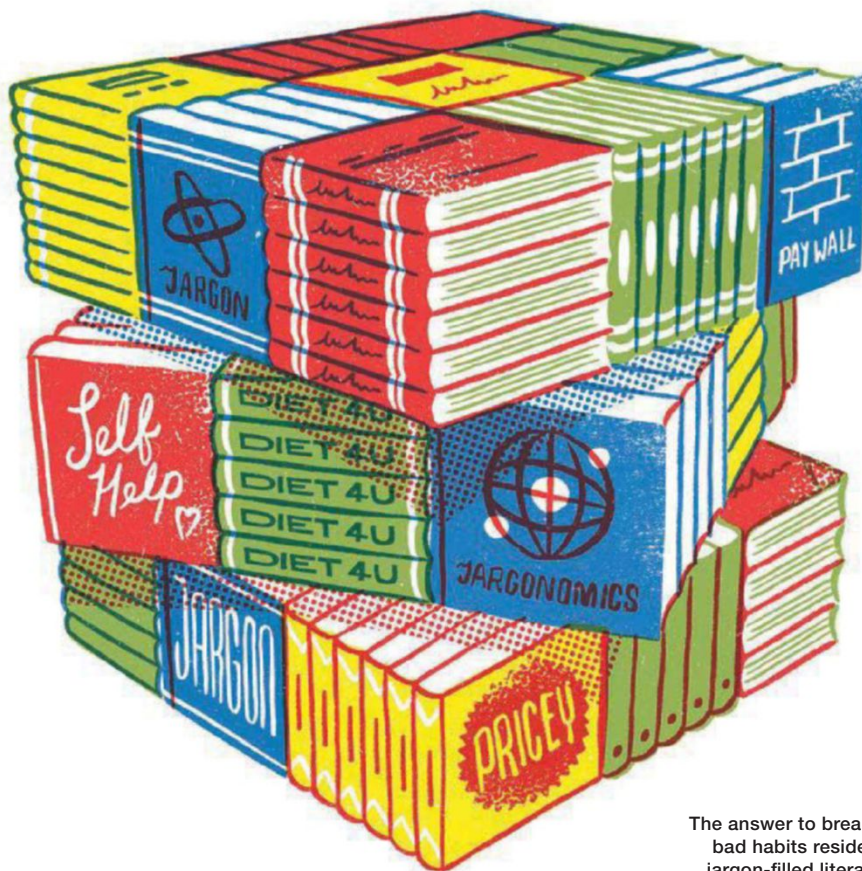
Shouldn't we – who pay for much of this stuff through taxes – insist that researchers study the issues we care about? The thing is, many of them do – it's just that their findings are stuck in academic literature.

Psychologists have been investigating ways of breaking bad habits for decades. The results have been scientifically tested and shown to work. But to find it, you first have to know where to look. Until recently, the only way to get free access to research papers was via academic libraries (a bit of a cheek, considering who paid for the research).

Now, Google Scholar will track down research on pretty much anything if fed a few keywords. But you still have to know the right keywords. Typing in 'breaking bad habits' turns up everything from systematic reviews to self-help books. Only by using the right jargon will you get the good stuff.

Terms like 'meta-analysis' help find studies on, say, dealing with heart attacks (sorry, myocardial infarctions). In the case of breaking bad habits, jargon such as 'goal attainment' puts you on the road to answers. Or, rather, it does if you can get past the journal paywalls that block access to those who, er, funded the research.

You can get round these by tracking down the researchers themselves to ask for a reprint – and hope it's not full of yet more jargon.



The answer to breaking bad habits resides in jargon-filled literature

“In the case of breaking bad habits, jargon such as ‘goal attainment’ puts you on the road to answers”

To save you the bother, I'll tell you what many researchers think is the best way to stick to particular objectives like New Year's resolutions. Set your goal, then think of common ways that it might get derailed – and plan how to respond.

Such plans are (bafflingly) known as 'implementation intentions', and usually come in the form of 'if-then' statements. So for someone on a diet, an implementation intention could be: "If I'm invited out for dinner, then I'll skip the booze and pudding". Many studies show that having such plans greatly boosts the chances of succeeding with resolutions.

Doubtless some self-help experts include this kind of advice in their pricey books-plus-dedicated-websites. But why should we have to pay yet again to find out what the academics all know, but are too busy writing grant requests to tell us about?

So I'd like to propose a New Year's resolution for researchers everywhere. Get together with your colleagues more often, and give us regular updates on what you know about life's little mysteries – without the jargon or the paywalls.

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham



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Monkeys Revealed

Premieres 29th March. Sundays at 7.05pm (JKT/BKK), 8.05pm (SIN/HK/MAL/TWN)

From India to Madagascar, Borneo to Peru, *Monkeys Revealed* travels the world meeting apes, monkeys and lemurs of all shapes and sizes, showcasing these animals' amazing behaviours and revealing just what makes our animal family so special.



Ocean Giants

Premieres 12th March.
Thursdays at 8.50pm (JKT/BKK),
9.50pm (SIN/HK/MAL/TWN)

Whales and dolphins remain a source of almost constant fascination to us. But how much do we really know about them? *Ocean Giants* goes in search of answers.



James May's Toy Stories: Action Man at the Speed of Sound

Premieres 17th March.
Thursdays at 8.00pm (JKT/BKK),
9.00pm (SIN/HK/MAL/TWN)

Join James May in his attempt to rehabilitate one of Britain's most derided toys by seeing if it's possible for Action Man to do what no toy has ever managed.



Bang Goes the Theory Sr 8

Tuesdays at 8.55pm (JKT/BKK),
9.55pm (SIN/HK/MAL/TWN)

A brand new season of the entertaining science magazine show packed with immersive challenges and amazing facts. In this series we ask, is there a connection between the recent flooding and global warming; can a Rolls Royce jet engine help detect secondary brain injuries?



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